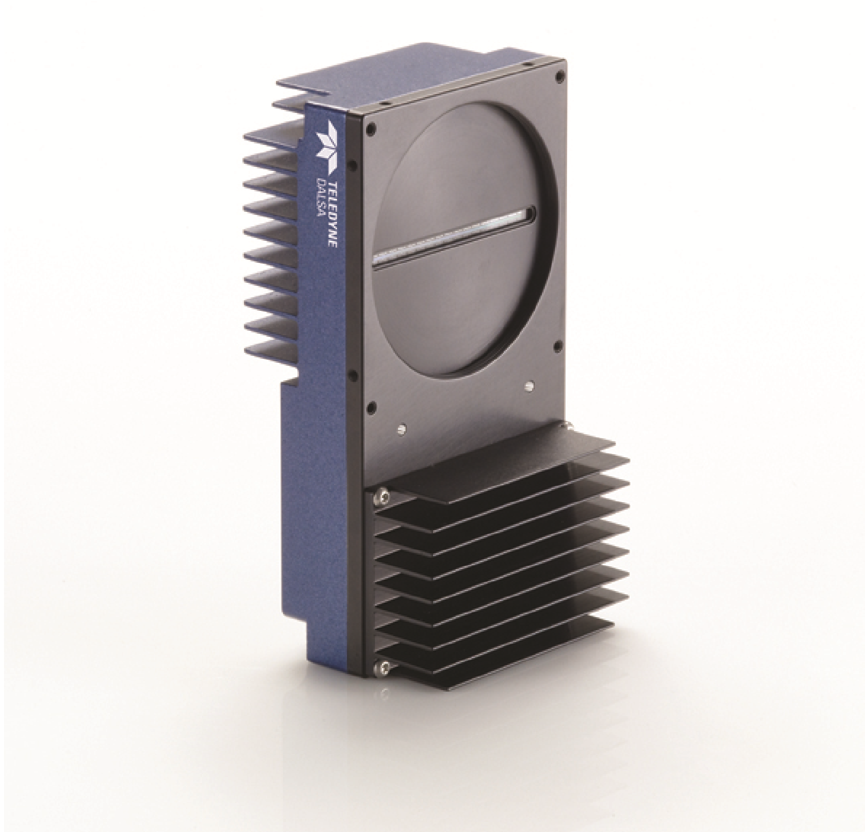
TDI Line Scan Camera with Enhanced QE in Near-Infrared

Piranha HS NIR

Camera User's Manual

HN-80-08k40-xx-R



TELEDYNE DALSA
Everywhereyoulook™

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Camera Highlights

Features

- 8192 pixels, 7 µm x 7 µm pixel pitch, 90% fill factor
- 16 taps, bidirectional TDI
- 281 megapixels/ second throughput
- 34 kHz line rate
- 100x antiblooming
- Broadband responsivity: 1240 $DN_{8\text{-bit}}$ / (nJ / cm^2) @0 dB
- Near-Infrared responsivity at 1000 nm of 430 $DN_{8\text{-bit}}$ (nJ / cm^2)
- 6 independently stage-selectable Time Delay and Integration (TDI) imaging regions for remarkable user-controlled sensitivity
- RoHS and CE compliant

Programmability

- Serial interface (ASCII, 115,200 baud), through Camera Link™.
- Programmable gain, offset, frame and frame rates, trigger mode, test pattern output, and camera diagnostics.
- Mirroring and forward/ reverse control.
- Selectable Area or TDI Mode of operation. Area Mode facilitates camera alignment and focusing. Area mode can also be used for regular operation.
- Selectable pixel size (2x2 and 4x4 binning).
- Flat-field correction—minimizes lens vignetting, non-uniform lighting, and sensor FPN and PRNU.
- Selectable Base, Medium, or Full Camera Link configuration.

Description

The Piranha HS NIR camera family represent Teledyne DALSA's latest generation of high sensitivity, TDI based cameras. The camera family maximizes system throughput. All cameras are capable of bi-directionality with up to 256 stages of integration.

Applications

This camera is ideal for applications requiring high speed, superior image quality, and high responsivity in visible and NIR light. These applications include:

- Solar cell inspection
- Postal sorting (flats)
- Flat panel display inspection
- Printed circuit board inspection
- High performance document scanning
- Large web inspection
- Low-light applications

Camera Performance Specifications

Table 1: Performance Specifications

Features and Specifications	
Model	**HN-80-08k40**
Imager Format	CCD Bidirectional TDI
Resolution	8196 pixels x 256 stages
Pixel Fill Factor	90 %
Pixel Size	7 µm x 7 µm
Output Format (# of Camera Link taps)	2, 4 or 8
Stage Selection	16, 64, 128, 192, 240, 256 stages
Antiblooming	100 x
CCD Shift Direction Change	0.02 seconds

Optical Interface	
Model	**HN-80-08k40**
Back Focal Distance	6.56 ± 0.25 mm
Sensor Alignment (aligned to sides of camera)	± 0.05 mm x ± 0.05 mm y ± 0.25 mm z ± 0.2 Θ z
Lens Mount Hole1	M72 x 0.75

Mechanical Interface	
Model	**HN-80-08k40**
Camera Size	80 (l) x 150 (h) x 65 (w)
Mass	650 g
Connectors	6 pin male Hirose, power MDR26 female, data

Electrical Interface	
Model	**HN-80-08k40**
Input Voltage	+ 12 to + 15 ± 5 % Volts DC
Power Dissipation[2]	18.5 W
Operating Temperature[3]	0 to 50 °C
Bit Width	8 or 12 bit user selectable bits
Output Data Configuration	Base, Medium or Full Camera Link

Operating Ranges	
Model	**HN-80-08k40**
Maximum Line Rate	34 kHz
Data Rate	Selectable 80, 160, 320 or 640 Mpix / sec
Gain	0 to +20 dB
Calibration Time	4.3 seconds

Performance	Gain 0 dB			Gain +20 dB		
	Min	**Typ**	**Max**	**Min**	**Typ**	**Max**
Dynamic Range	1000	1333				
Random Noise DN_{8bit} rms		0.18	0.25		1.8	2.5
SEE pJ / cm^2		200				
NEE pJ / cm^2		0.15	0.2			
Analog Broadband Responsivity (DN_{8bit} / nJ / cm^2)		1240				
FPN DN p-p		0.13	1		0.93	
PRNU DN_{8bit} p-p		1.33	3		12.9	
Saturation Output Amplitude DN_{8bit}	255 typ					
DC Offset DN_{8bit}	3 min			5 typ		6 max

Test conditions for all models, unless otherwise noted:

- TDI mode of operation. These specifications are not guaranteed for area mode of operation.
- Line Rate: 10 kHz.
- Nominal Gain setting.
- Light Source: Broadband Quartz Halogen, 3250 k, with 700 nm IR cut-off filter installed.
- All Max specifications are valid over a 0-50 °C temperature range.
- All Typ specifications are measured at 25 °C.

- All values are referenced at 8-bit.

1. Maximum using highest Camera Link mode and maximum line rate.
2. Measured at the front plate.

Image Sensor

The camera uses Teledyne DALSA's newest bidirectional TDI sensors. The camera can be configured to read out in either Forward or Reverse CCD shift direction. Readout direction is controlled by the software command `scd`.

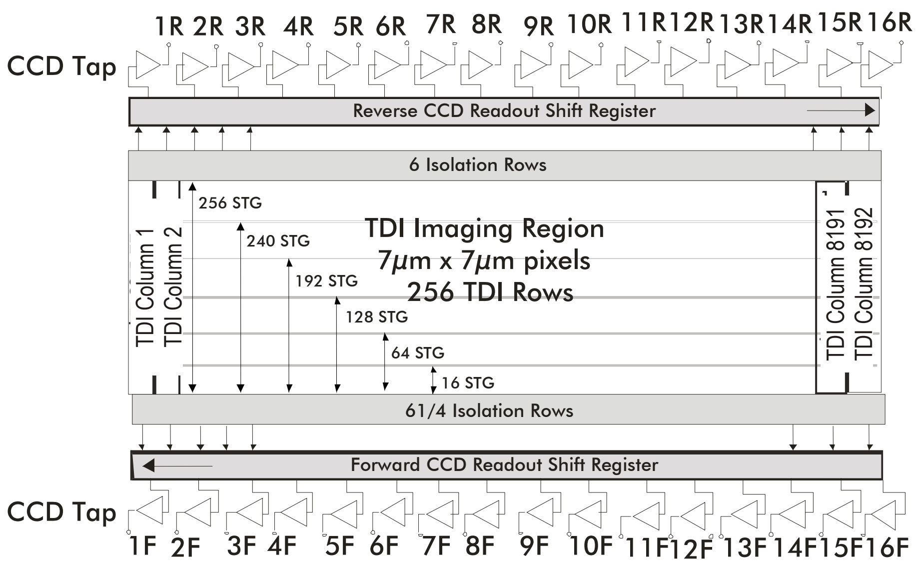


Figure 1: 16 Tap Sensor Block Diagram (HN-80-08k40)

Responsivity

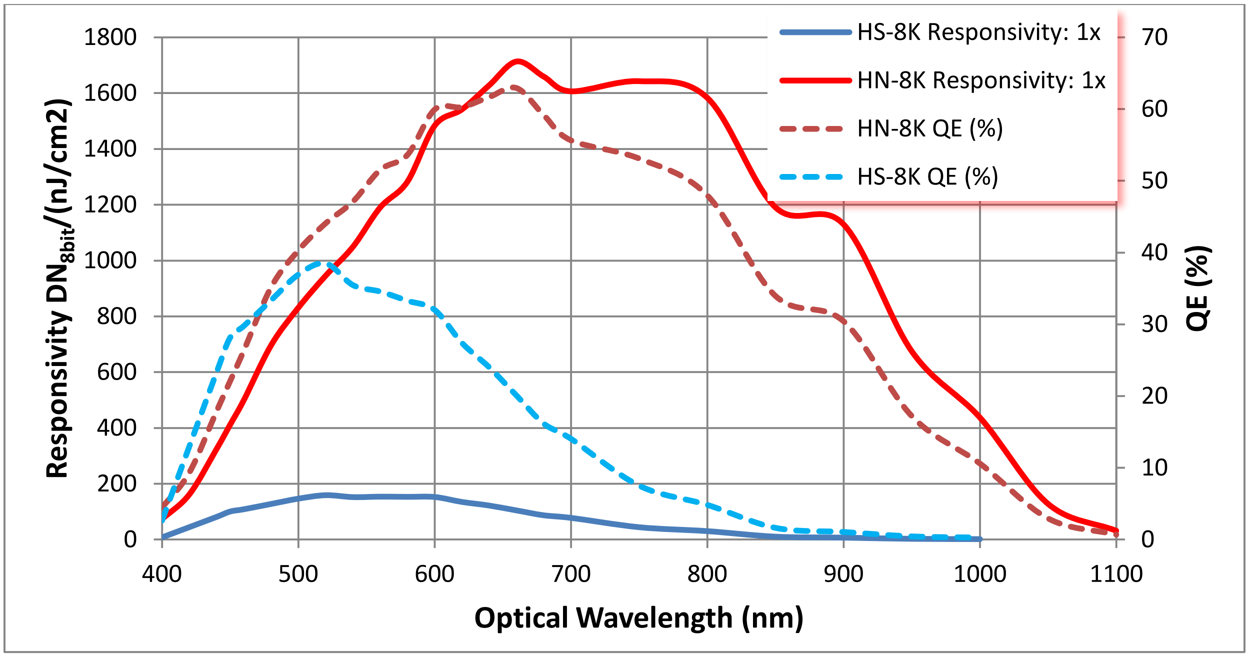


Figure 2: Responsivity

2. Quick, Simple Steps to Acquire an Image

For users who are familiar with Camera Link cameras, have a basic understanding of their imaging requirements, and who are primarily interested in evaluating the camera, an overview of the steps required to get this camera operational and acquiring images quickly can be found in Appendix B: Quick Setup and Image Acquisition.

2. Camera Hardware Interface

Installation Overview

When installing your camera, you should take these steps:

This installation overview assumes you have not installed any system components yet.

1. Power down all equipment.
2. Follow the manufacturer's instructions to install the frame grabber (if applicable). **Be sure to observe all static precautions.**
3. Install any necessary imaging software.
4. Before connecting power to the camera, test all power supplies. **Ensure that all the correct voltages are present at the camera end of the power cable.** Power supplies must meet the requirements defined in the Power Connector section.
5. Inspect all cables and connectors prior to installation. Do not use damaged cables or connectors or the camera may be damaged.
6. Connect Camera Link and power cables.
7. After connecting cables, apply power to the camera.
8. Check the diagnostic LED.

You must also set up the other components of your system, including light sources, camera mounts, host computers, optics, encoders, and so on.

Input / Output Connectors and LED

The camera uses:

- One diagnostic LED for monitoring the camera.
- Two high-density 26-pin MDR26 connectors for Camera Link control signals, data signals, and serial communications. One for base, medium or full configuration (labelled "CONTROL & DATA 1") and one for medium or full configuration ("CONTROL 2").
- One 6-pin Hirose connector for power..

LED Status Indicator

The camera is equipped with a red/ green LED used to display the operational status of the camera. The table below summarizes the operating states of the camera and the corresponding LED states.

When more than one condition is active, the LED indicates the condition with the highest priority. Error and warning states are accompanied by corresponding messages further describing the current camera status.

Table 2: Diagnostic LED

Priority	Color of Status LED	Meaning
1	Flashing Red	Fatal Error. Camera temperature is too high and camera thermal shutdown has occurred or a power on failure has been detected.
2	Solid Red	Warning. Loss of functionality.
3	Flashing Green	Camera initialization or executing a long command (e.g., flat field

Priority	Color of Status LED	Meaning
		correction command `ccf`)
4	Solid Green	Camera is operational and functioning correctly.

Power Connector

Figure 3: Hirose 6-pin Circular Male—Power Connector

Table 3: Hirose Pin Description

Pin	Description	Pin	Description
1	Min +12 to Max +15VDC	4	GND
2	Min +12 to Max +15VDC	5	GND
3	Min +12 to Max +15VDC	6	GND

The camera requires a single voltage input (+12 to +15VDC). The camera meets all performance specifications using standard switching power supplies, although well-regulated linear supplies provide optimum performance.

WARNING: When setting up the camera's power supplies follow these guidelines:

- Apply *only* the appropriate voltages. Incorrect voltages will damage the camera.
- Protect the camera with a **fast-blow fuse** between power supply and camera.
- Do not use the shield on a multi-conductor cable for ground.
- Keep leads as short as possible to reduce voltage drop.
- Use high-quality **linear** supplies to minimize noise.
- Use an isolated type power supply to prevent LVDS common mode range violation.

Note: Camera performance specifications are not guaranteed if your power supply does not meet these requirements.

Teledyne DALSA offers a power supply with attached 6' power cable that meets the Piranha HS camera's requirements, but it should not be considered the only choice. Many high quality supplies are available from other vendors.

Camera Link Data Connector

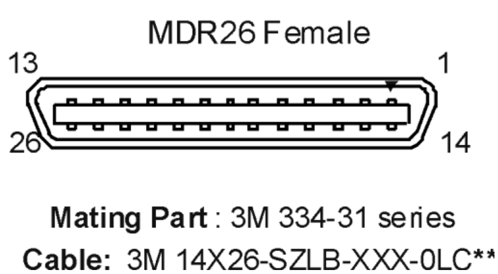


Figure 4: Camera Link MDR26 Connector

The Camera Link interface is implemented as a Base, Medium or Full Configuration in the camera. The following table summarizes the different configurations and lists the configurations available to each Piranha HS model number.

Table 4: Camera Link Hardware Configuration Summary

Configuration	8 Bit Ports Supported	Serializer Bit Width	Number of Chips	Number of MDR26 Connectors
Base	A, B, C	28	1	1
Medium	A, B, C, D, E, F	28	2	2
Full	A, B, C, D, E, F, G, H	28	3	2

Table 5: Camera Link Connector Pinout

Medium and Full Configurations					Base Configuration		
Up to an additional 2 Channel Link Chips					One Channel Link Chip + Camera Control + Serial Communication		
Camera Connector	Right Angle Frame Grabber	Channel Link Signal	Cable Name		Camera Connector	Right Angle Frame Grabber	Channel Link Signal
1	1	inner shield	Inner Shield		1	1	inner shield
14	14	inner shield	Inner Shield		14	14	inner shield
2	25	Y0-	PAIR1-		2	25	X0-
15	12	Y0+	PAIR1+		15	12	X0+
3	24	Y1-	PAIR2-		3	24	X1-
16	11	Y1+	PAIR2+		16	11	X1+
4	23	Y2-	PAIR3-		4	23	X2-
17	10	Y2+	PAIR3+		17	10	X2+
5	22	Yclk-	PAIR4-		5	22	Xclk-
18	9	Yclk+	PAIR4+		18	9	Xclk+
6	21	Y3-	PAIR5-		6	21	X3-
19	8	Y3+	PAIR5+		19	8	X3+
7	20	100 ohm	PAIR6+		7	20	SerTC+
20	7	terminated	PAIR6-		20	7	SerTC-
8	19	Z0-	PAIR7-		8	19	SerTFG-
21	6	Z0+	PAIR7+		21	6	SerTFG+
9	18	Z1-	PAIR8-		9	18	CC1-
22	5	Z1+	PAIR8+		22	5	CC1+
10	17	Z2-	PAIR9+		10	17	CC2+
23	4	Z2+	PAIR9-		23	4	CC2-
11	16	Zclk-	PAIR10-		11	16	CC3-
24	3	Zclk+	PAIR10+		24	3	CC3+
12	15	Z3-	PAIR11+		12	15	CC4+
25	2	Z3+	PAIR11-		25	2	CC4-
13	13	inner shield	Inner Shield		13	13	inner shield
26	26	inner shield	Inner Shield		26	26	inner shield

Notes:

*Exterior Overshield is connected to the shells of the connectors on both ends.
**3M part 14X26-SZLB-XXX-0LC is a complete cable assembly, including connectors.
Unused pairs should be terminated in 100 ohms at both ends of the cable.
Inner shield is connected to signal ground inside camera

Table 6: Teledyne DALSA Camera Control Configuration

Signal	Configuration
CC1	EXSYNC
CC2	Spare
CC3	Forward
CC4	Spare

See Camera Link Configuration Tables for the complete Teledyne DALSA Camera Link configuration tables, and refer to the Teledyne DALSA Web site, Knowledge Center application notes, for the official Camera Link documents.

Input Signals, Camera Link

The camera accepts control inputs through the Camera Link MDR26F connector.

The camera ships in internal sync, internal programmed integration (exposure mode 7) TDI Mode.

EXSYNC (Triggers Frame Readout)

Frame rate can be set internally using the serial interface. The external control signal EXSYNC is optional and enabled through the serial interface. This camera uses the **falling edge of EXSYNC** to trigger pixel readout. See section Exposure Mode and Line/ Frame Rate for details on how to set frame times, exposure times, and camera modes.

Direction Control

You control the CCD shift direction through the serial interface. With the software command, `scd`, you determine whether the direction control is set via software control or via the Camera Link control signal on CC3. Refer to section Setting the Camera's CCD Shift Direction for details.

Output Signals, Camera Link

These signals indicate when data is valid, allowing you to clock the data from the camera to your acquisition system. These signals are part of the Camera Link configuration and you should refer to the Teledyne DALSA Camera Link Implementation Road Map, available at the Knowledge Center, for the standard location of these signals.

Clocking Signal	Indicates
LVAL (high)	Outputting valid line
DVAL (high)	Valid data
STROBE (rising edge)	Valid data
FVAL (high)	Outputting valid frame

IMPORTANT: This camera's data should be sampled on the rising edge of STROBE.

The camera internally digitizes to 14 bits and outputs 8 or 12 MSB bits depending on the camera's Camera Link operating mode. Refer to Setting the Camera Link Mode for details.

3. Mechanical Interface

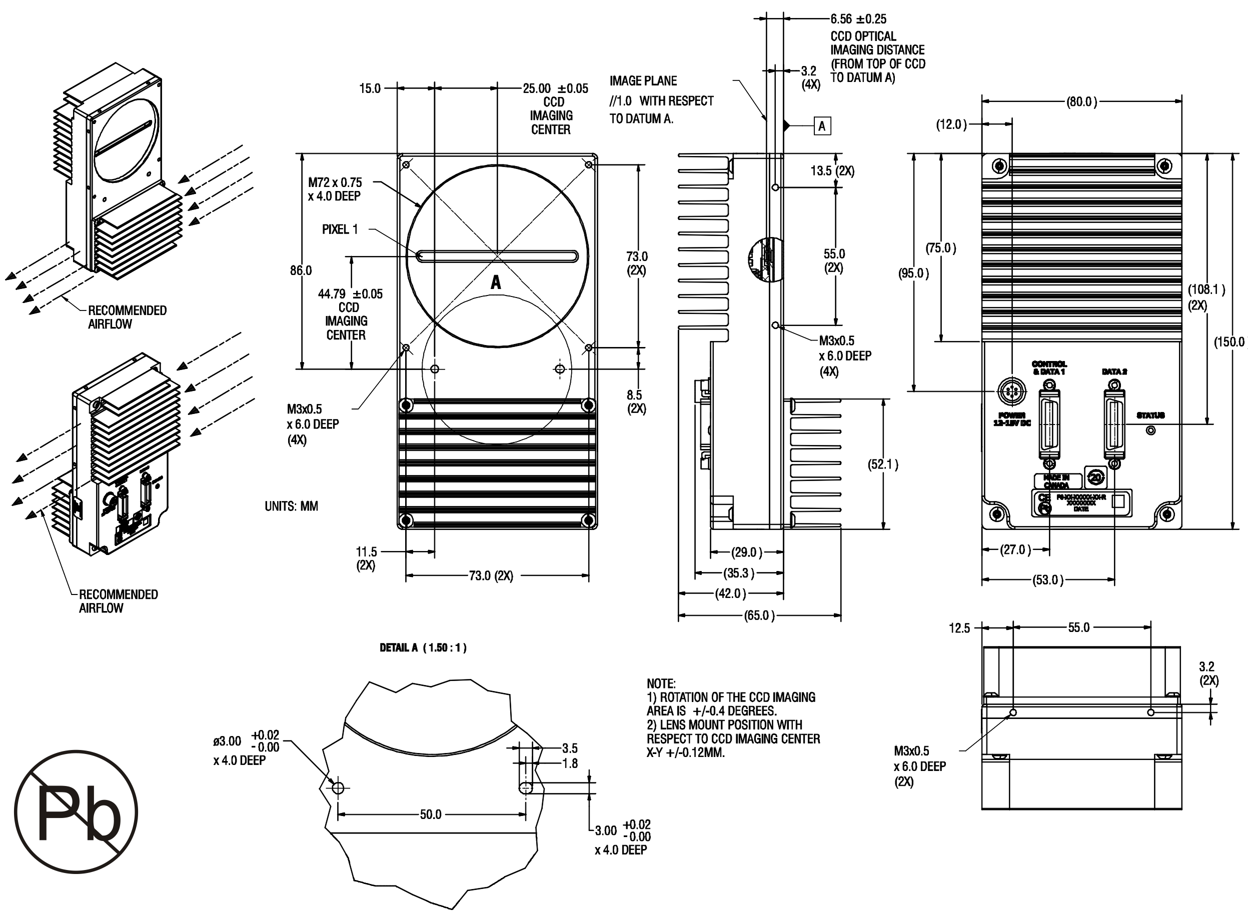


Figure 5: Mechanical Dimensions

Lens Mounts

Model Number	Lens Mount Options
HN-80	M72x0.75 thread.

Optical Interface

Illumination

The amount and wavelengths of light required to capture useful images depend on the particular application. Factors include the nature, speed, and spectral characteristics of objects being imaged, exposure times, light source characteristics, environmental and acquisition system specifics, and more.

It is often more important to consider exposure than illumination. The total amount of energy (which is related to the total number of photons reaching the sensor) is more important than the rate at which it arrives. For example, $5\mu J/cm^2$ can be achieved by exposing $5mW/cm^2$ for 1ms just the same as exposing an intensity of $5W/cm^2$ for $1\mu s$.

Light Sources

Keep these guidelines in mind when setting up your light source:

LED light sources are relatively inexpensive, provide a uniform field, and longer life span compared to other light sources. However, they also require a camera with excellent sensitivity, such as the HN-xx camera.

Halogen light sources generally provide very little blue relative to infrared light (IR).

Fiber-optic light distribution systems generally transmit very little blue relative to IR.

Some light sources age; over their life span they produce less light. This aging may not be uniform—a light source may produce progressively less light in some areas of the spectrum but not others.

Filters

In visible light applications, CCD cameras are extremely responsive to infrared (IR) wavelengths of light. To prevent infrared from distorting the images you scan, use a “hot mirror” or IR cutoff filter that transmits visible wavelengths but does not transmit wavelengths over 750nm. Examples are the Schneider Optics™ B+W 489, which includes a mounting ring, the CORION™ LS-750, which does not include a mounting ring, and the CORION™ HR-750 series hot mirror.

In NIR imaging applications, a visible light cutoff filter is recommended.

Lens Modeling

Any lens surrounded by air can be modeled for camera purposes using three primary points: the first and second principal points and the second focal point. The primary points for a lens should be available from the lens data sheet or from the lens manufacturer. Primed quantities denote characteristics of the image side of the lens. That is, h is the object height and h' is the image height.

The *focal point* is the point at which the image of an infinitely distant object is brought to focus. The *effective focal length (f')* is the distance from the second principal point to the second focal point. The *back focal length (BFL)* is the distance from the image side of the lens surface to the second focal point. The *object distance (OD)* is the distance from the first principal point to the object.

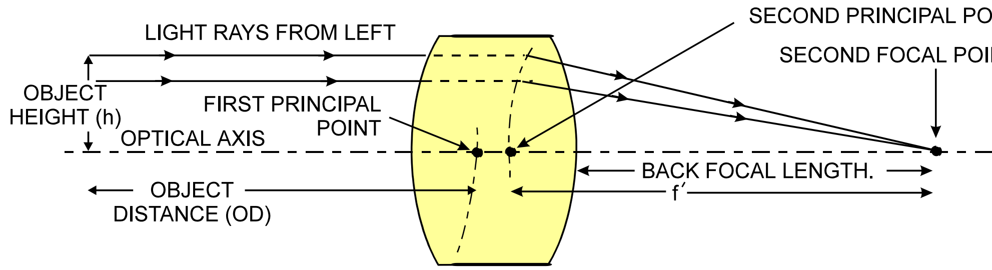


Figure 6: Primary Points in a Lens System

4. Software Interface: How to Control the Camera

All camera features can be controlled through the serial interface. The camera can also be used without the serial interface after it has been set up correctly. Functions available include:

- Controlling basic camera functions such as gain and sync signal source.
- Flat field correction.
- Mirroring and readout control.
- Generating a test pattern for debugging.

The serial interface uses a simple ASCII-based protocol and the PC does not require any custom software.

Note: This command set has changes from previous Teledyne DALSA cameras. Do not assume that the Piranha HS NIR commands perform similarly to older cameras.

Serial Protocol Defaults

- 8 data bits
- 1 stop bit
- No parity
- No flow control
- 115,200 kbps (fixed)
- Camera does not echo characters

Command Format

When entering commands, remember that:

- A carriage return <CR> ends each command.
- A space or multiple space characters separate parameters. Tabs or commas are invalid parameter separators.
- Upper and lowercase characters are accepted
- The backspace key is supported
- The camera will answer each command with either <CR><LF> “OK >" or <CR><LF>"Error xx: Error Message >" or <CR><LF>“Warning xx: Warning Message >”. The ">" is used exclusively as the last character sent by the camera.

The following parameter conventions are used in the manual:

- ***i*** = integer value
- ***f*** = real number
- ***m*** = member of a set
- ***s*** = string
- ***t*** = tap id
- ***x*** = pixel column number

- ***y*** = pixel row number

Example:

To return the current camera settings `gcp` <CR>

Camera Help Screen

For quick help, the camera can return all available commands and parameters through the serial interface.

There are two different help screens available. One lists all of the available commands to configure camera operation. The other help screen lists all of the commands available for retrieving camera parameters (these are called "get" commands).

To view the help screen listing all of the camera configuration commands, use the command:

Syntax:	**h**

To view a help screen listing all of the "get" commands, use the command:

Syntax:	**gh**
Notes:	For more information on the camera's "get" commands, refer to Returning Camera Settings.

The camera configuration command help screen lists all commands available. Parameter ranges displayed are the extreme ranges available. Depending on the current camera operating conditions, you may not be able to obtain these values. If this occurs, values are clipped and the camera returns a warning message.

Some commands may not be available in your current operating mode. The help screen displays NA in this case.

Example Help Screen for HN-80-08k40 TDI Mode Operation

```
OK>h
ccf  correction calibrate fpn
ccg  calibrate camera gain        i      4096-16064
clm  camera link mode             m      2/3/15/16/21
cpa  calibrate PRNU algorithm     mi     2/4/:4096-16220
css  correction set sample        m      1/1024/2048/4096
dpc  display pixel coeffs         xx     1-8192:1-8192
gcl  get command log
gcm  get camera model
gcp  get camera parameters
gcs  get camera serial
gcv  get camera version
get  get values                   s
gfc  get fpn coeff                x      1-8192
gh   get help
gl   get line                     xx     1-8192:1-8192
gla  get line average             xx     1-8192:1-8192
gpc  get prnu coeff               x      1-8192
```

Command

Parameters
i = integer
f = floating point number
m = member of a set
s = string
t = tap
x = pixel column number
y = pixel row number

Parameter Range
- = range
: = multiple parameter separator
/ = member of a set separator
NA = command not available in current operating mode

```
gsf  get signal frequency          m       1/3/
h    help
?    single command help           s
lpc  load pixel coefficients
rc   reset camera
rfs  restore factory settings
roi  region of interest            xyxy    1-8192:1-1:1-8192:1-1
rpc  reset pixel coeffs
rus  restore user settings
sab  set add background            i       0-4096
sbh  set binning horizontal        m       1/2/4
sbv  set binning vertical          m       1/2/4
scd  set ccd direction             i       0-2
sdh  set digital horizontal binningm       1/2/4
sdv  set digital vertical binning  m       1/2/4
sem  set exposure mode             m       3/7/
sfc  set fpn coeff                 xi      1-8192:0-8191
sg   set gain                      f       -20-+20
smm  set mirroring mode            i       0-1
sot  set output throughput         m       160/320/
spc  set prnu coeff                xi      1-8192:0-61438
spr  set prnu range                xxi     1-8192:1-8192:0-61438
ssb  set subtract background       i       0-4096
ssf  set sync frequency            f       1-34246
ssg  set system gain               i       0-61438
ssn  set set number                i       0-4
stg  set stage selection           m       16/64/128/192/240/256/
svm  set video mode                i       0-4
tdi  set tdi/area mode             i       0-1
ugr  update gain reference
vt   verify temperature
vv   verify voltage
wfc  write FPN coefficients
wpc  write PRNU coefficients
wus  write user settings
OK>
```

Example Help Screen for HN-80-08k40 Area Mode Operation

```
OK>h
ccg  calibrate camera gain         i       4096-16064
clm  camera link mode              m       2/3/15/16/21
gcl  get command log
gcm  get camera model
gcp  get camera parameters
gcs  get camera serial
gcv  get camera version
get  get values                    s
gh   get help
gl   get line                      xx      1-8192:1-8192
```

```
gla  get line average              xx      1-8192:1-8192
gsf  get signal frequency          m       1/3/
h    help
?    single command help           s
rc   reset camera
rfs  restore factory settings
rus  restore user settings
sab  set add background            i       0-4096
sbh  set binning horizontal        m       1/2/4
sbv  set binning vertical          m       1/2/4
scd  set ccd direction             i       0-2
sdh  set digital horizontal binningm       1/2/4
sem  set exposure mode             m       3/7/
sg   set gain                      f       -20-+20
smm  set mirroring mode            i       0-1
sot  set output throughput         m       320/640
spr  set prnu range                xxi     1-8192:1-8192:0-61438
ssb  set subtract background       i       0-4096
ssf  set sync frequency            f       1-130
ssg  set system gain               i       0-61438
ssn  set set number                i       0-4
stg  set stage selection           m       16/64/128/192/240/256/
svm  set video mode                i       0-4
tdi  set tdi/area mode             i       0-1
ugr  update gain reference
vt   verify temperature
vv   verify voltage
wus  write user settings
OK>
```

First Power Up Camera Settings

When the camera is powered up for the first time, it operates using the following factory settings:

- TDI mode
- Left to right pixel readout
- Forward CCD shift direction
- 256 integration stages
- No binning
- Camera Link Mode 21 (8 bit, 8 taps)
- Exposure mode 7
- 7.5kHz line rate
- 640 throughput
- Factory calibrated analog gain and offset

Factory calibrated FPN and PRNU coefficients using the following process:

ssf	7500	(line rate of 7.5 kHz)
ccg	12800	(gain calibrated to an average pixel value of 3200)

`ccf`		(fpn calibration)
`cpa 2`	16000	(prnu calibrated to an average pixel value of 4000)

Command Categories

The following diagram categorizes and lists all of the camera's commands. This chapter is organized by command category.

Sensor Output Format

TDI or Area Mode (tdi)
Number of Integration Stages (stg)
CCD Shift Direction (scd)
Analog Binning (sbv and sbh)
Digital Binning (sdv and sdh)
Set Exposure Mode (sem)
Set Frame/Line Rate (ssf)

Camera Output Format

Camera Link Mode (clm)
Camera Throughput (sot)
Pixel Readout Direction (smm)
Generate a Test Pattern (svm)

Data Processing

Region of Interest (roi)
Update Gain Reference (ugr)
Correction Set Sample (css)
Calculate FPN (ccf)
Calibrate Camera Gain (ccg)
Set Gain (sg)
Calculate PRNU Algorithm (cpa)
Set PRNU Coefficient (spc)
Set FPN Coefficient (sfc)
Set Addition Background (sab)
Set Subtraction Background (ssb)
Set System Gain (ssg)

Saving and Restoring Settings

Save Current User Settings (wus)
Restore Previously Saved User Settings (rus)
Save Current PRNU Coefficients (wpc)
Save Current FPN Coefficients (wfc)
Load Pixel Coefficients (lpc)
Reset Pixel Coefficients (rpc)
Restore Factory Settings (rfs)
Reboot Camera (rc)

Diagnostics

Get Line of Data (gl)
Get an Average of Multiple Lines (gla)
Display Pixel Coefficients (dpc)
Measure Internal Temperature (vt)
Measure Input Voltage (vv)
Get Commands

Other

Help (h)

Figure 7: Command Categories

Sensor Output Format

Selecting TDI or Area Mode Operation

The camera has the ability to operate in either TDI or Area Mode.

In Area Mode, the camera operates as an area array camera using a two dimensional array of pixels. Area Mode is useful for aligning the camera to your web direction or when you need a rectangular 2D image and the lighting supports a full frame imager.

In TDI Mode, the camera operates as a TDI high sensitivity line scan camera and combines multiple exposures of an object into one high-resolution result.

The camera stores user settings for Area Mode and TDI Mode separately, allowing you to switch between Area and TDI mode without losing settings specific to each mode. See Saving and Restoring Settings for an explanation on how user settings are stored and retrieved.

Note: Sensor cosmetic specifications for Area Mode of operation are neither tested nor guaranteed

Purpose:	Selects the camera's operating mode. Area Mode is useful for aligning and focusing your camera.
Syntax:	**`tdi`** ***`i`***
Syntax Elements:	***`i`*** **`0`** Area mode **`1`** TDI mode
Notes:	• Remember to save your user settings before changing mode. Sending the **`tdi`** command always restores your last saved user settings for the mode of operation requested even if you are already operating in the requested mode. • Flat field correction is not available in Area Mode.
Example	**`tdi 1`**

Selecting the Number of CCD Integration Stages

Purpose:	In TDI Mode, this command adjusts the sensitivity level in your camera by setting the number of CCD integration stages. In Area Mode, the vertical height of the image sensor is controlled by the number of stages.
Syntax:	**`stg`** ***`m`***
Syntax Elements:	***`m`*** Number of stages to use. Available values are **`16`**, **`64`**, **`128`**, **`192`**, **`240`**, and **`256`**. Factory setting is **`256`**.
Notes:	• **`The optical flat field correction will require re-calibrating after changing the stage selection by using the ccf and cpa commands.`**
Example	**`stg 64`**

Setting the Camera's CCD Shift Direction

Purpose: When in TDI Mode, selects the forward or reverse CCD shift direction or external direction control. This accommodates object direction change on a web and allows you to mount the camera "upside down".

In Area Mode, selects the vertical readout direction. This allows you to mirror the image vertically or mount the camera "upside down".

Syntax: **scd *i***

Syntax Elements: ***i***

Readout direction. Allowable values are:

0 = Forward CCD shift direction.

1 = Reverse CCD shift direction.

2 = Externally controlled direction control via Camera Link control CC3 (CC3=1 forward, CC3=0 reverse). Available only in TDI Mode.

Notes:

- The following user settings are stored separately for forward and reverse direction; digital gain, system gain, background subtract, digital gain, background addition and pixel coefficients. These settings are automatically loaded when you switch direction. All other settings are common to both directions.
- See the following figures for an illustration of CCD shift direction in relation to object movement.
-

Example **scd 1**

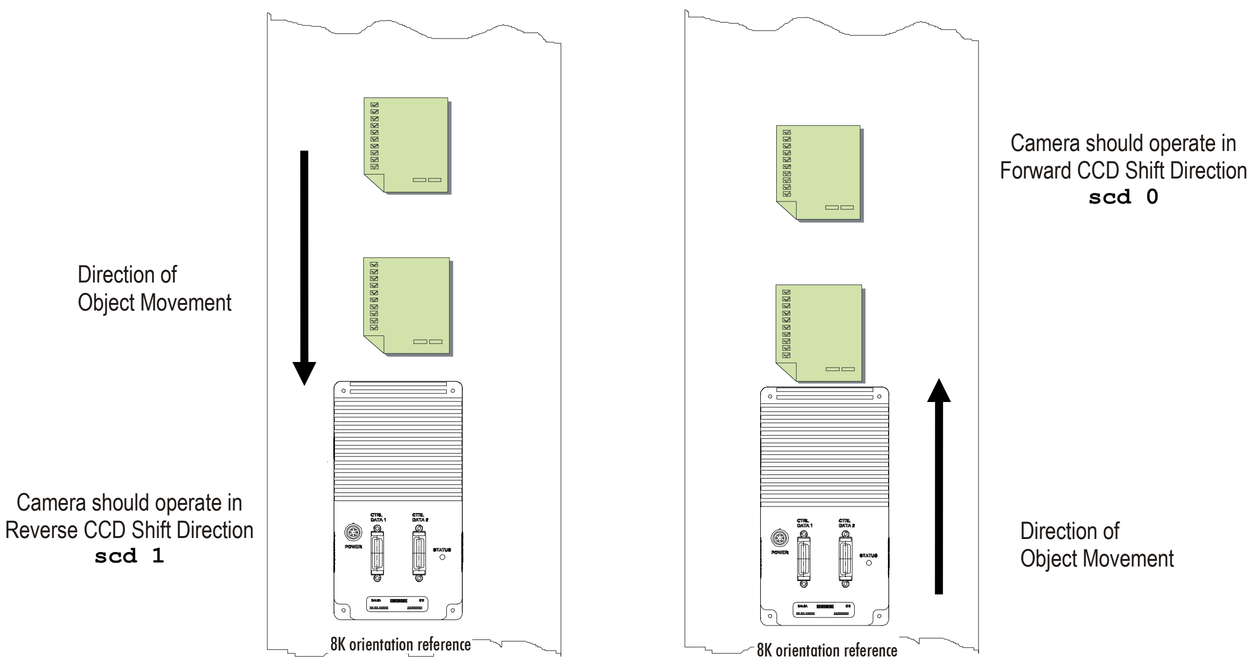


Figure 8: Object Movement and Camera Direction Example using 4k Model and an Inverting Lens

Increasing Sensitivity with Binning

Binning increases the camera's light sensitivity by decreasing horizontal and/ or vertical resolution—the charge collected by adjacent pixels is added together. Binning is also useful for increasing frame rate (vertical binning) or increasing the pixel pitch. For example, if you set your vertical binning to 2 and your horizontal binning to 2, your pixel size increases from 7µm x 7µm (no binning) to 14 µm x 14 µm (2 x 2 binning).

Generally, digital binning prevents sensor blooming, while analog binning is better for noise. For 2x binning in either direction, the noise is improved by a factor of 2 in analog binning and sqrt2 in digital binning.

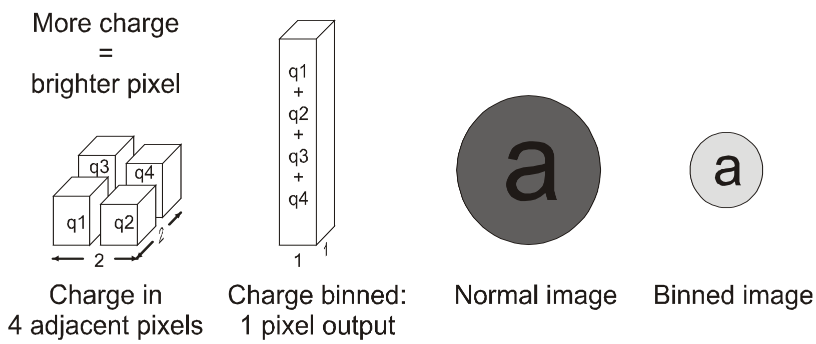


Figure 9: 2x2 Binning in Area Mode

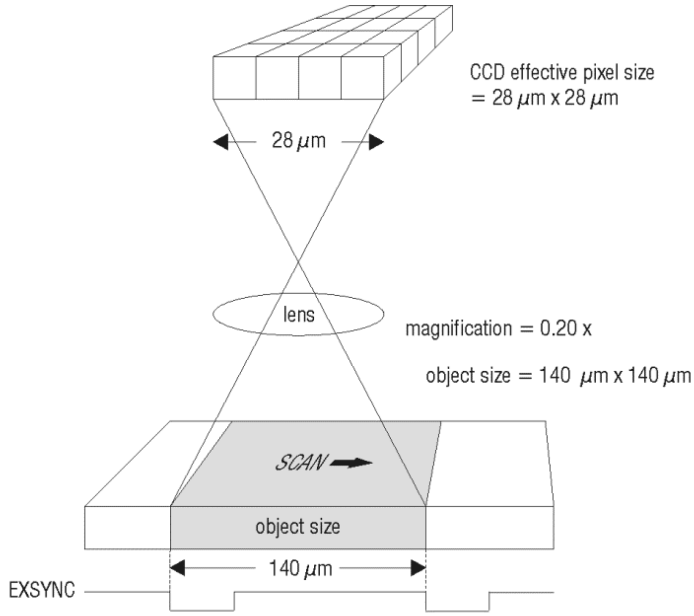
EXSYNC Considerations with Binning

A line scan and TDI scan CCD both require a synchronization signal (EXSYNC) to track the relative motion between the CCD and the object to be imaged. The EXSYNC signal is provided by the mechanical system that controls the motion and is typically generated by a shaft encoder. The shaft encoder is configured to provide one signal every time the relative distance travelled is equal to the "object pixel" size. The object pixel size is determined by the magnification factor of the lens. For example, with a 7x7 um ccd pixel and with a 0.5 x magnification, the object pixel size is 14x14 um. In other words, the smallest feature that the CDD can distinguish is 14 um. In this system, the shaft encoder should be configured to provide a pulse each time the object moves by 14 um. This principle applies for both a line scan (1 line) and TDI scan type CCD.

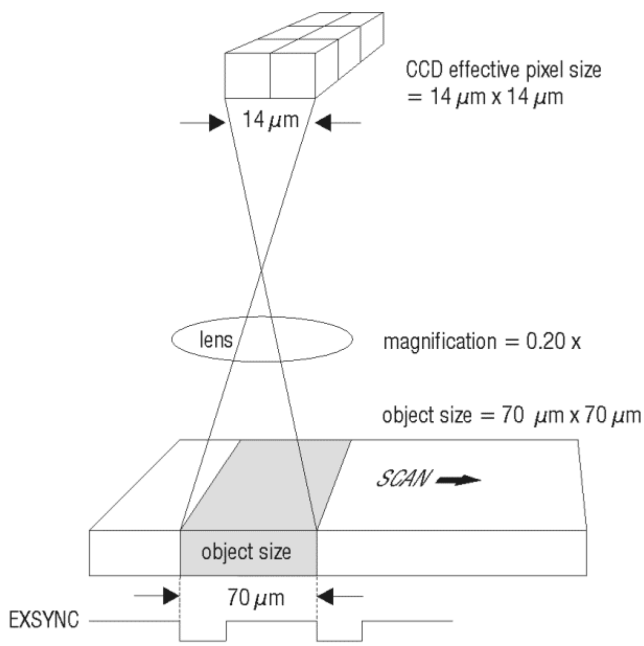
The TDI CCD can provide the additional feature called binning in which groups of pixels can be added together or "binned". This provides for a higher response at the expense of lower resolution. For example, with 2x2 binning of pixels of 7x7 um each, the effective pixel size is now 14x14 um. Careful consideration must be given to the EXSYNC signal when binning is enabled since binning will change the object pixel size. With a 0.5x magnification, the new 14 um pixel provides a object pixel size of 28x28 um. Therefore, the EXSYNC signal from the shaft encoder must be re-configured to provide a pulse each time the object moves by 28 um.

Note: If the speed of the liner motion remains the same with no binning and with 2x2 binning, then the EXSYNC frequency with 2x2 binning will then become ½ the frequency used for no binning.

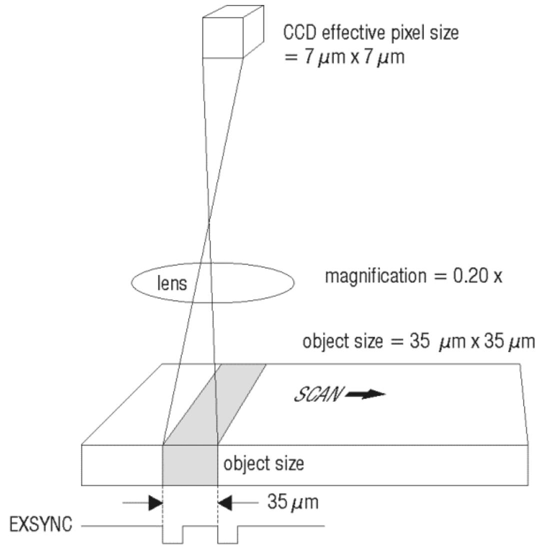
The same principle applies with 4x4 binning. The shaft encoder pulse occurrence must be re-configured for the new and bigger object pixel size.



4x Binning, Fixed Magnification



2x Binning, Fixed Magnification



No Binning, Fixed Magnification

Figure 10: Relationship between EXSYNC and binning illustrated

Setting Horizontal Analog Binning

Purpose: Increases the horizontal pixel pitch and light sensitivity by decreasing horizontal resolution. The amount of data being sent from the camera is reduced by the horizontal binning factor. Different frame grabber files are needed for different horizontal binning factors.

Syntax: **`sbh`** ***`m`***

Syntax Elements: **`m`**

Horizontal analog binning value. Available values are **`1`** (factory setting, no binning) **`2`**, or **`4`**.

Notes:

- If you are using horizontal binning, the min, max, and mean statistics generated by the **`gl`** or **`gla`** command are for every second pixel (or valid data) only (e.g., if **`sbh 2`**, every second pixel).
- For optimal flat field correction, you should rerun the **`ccf`** and **`cpa`** commands after changing binning values.
- Changing binning values does not automatically alter gain, external frame rate generation, or other functions of the camera.
- Pixel numbering remains unchanged for the **`roi`**, **`gl`**, **`gla`**, **`gfc`**, **`sfc`**, **`gpc`**, and **`spc`** commands. Refer to Figure 19 for an explanation of pixel numbering and pixel start and stop values when using a region of interest.
- Command **`sdh`** set to default (**`1`**).

Example: **`sbh 2`**

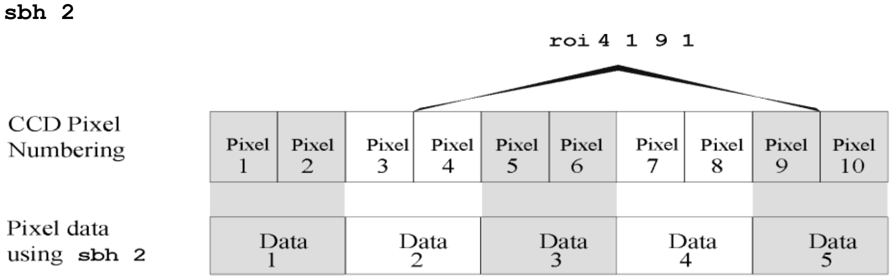


Figure 11: Binning Start and End Values when using a Region of Interest

In this example a region of interest is set to include pixels 4 to 9 and horizontal binning is set to 2. Because pixel 3 is now included in the same data group as pixel 4, the region of interest will now include the data from pixel 3. Also, pixel 10 is included in the same data group as pixel 9, so pixel 10 is now part of the region of interest. To see how the region of interest start and stop values have been rounded, use the command **`get roi`**.

Setting Horizontal Digital Binning

Purpose: Increases the horizontal pixel pitch and light sensitivity by decreasing horizontal resolution. The amount of data being sent from the camera is reduced by the horizontal binning factor. Different frame grabber files are needed for different horizontal binning factors.

Syntax: **`sdh`** ***`m`***

Syntax Elements: **`m`**

Horizontal digital binning value. Available values are **`1`** (factory setting, no binning) **`2`**, or **`4`**.

Notes:

- If you are using horizontal binning, the min, max, and mean statistics generated by the **`gl`** or **`gla`** command are for every second pixel (or valid data) only (e.g., if **`sbh 2`**, every second pixel).
- For optimal flat field correction, you should rerun the **`ccf`** and **`cpa`** commands after changing binning values.
- Changing binning values does not automatically alter gain, external frame rate generation, or other functions of the camera.
- Pixel numbering remains unchanged for the **`roi`**, **`gl`**, **`gla`**, **`gfc`** , **`sfc`** , **`gpc`**, and **`spc`** commands. Refer to Figure 19 for an explanation of pixel numbering and pixel start and stop values when using a region of interest.
- Command **`sbh`** set to default (**`1`**).

Example: **`sdh 2`**

Setting Vertical Analog Binning

Syntax: Increases the vertical pixel pitch and light sensitivity by decreasing vertical resolution. Vertical analog binning is also useful for increasing frame rate in Area Mode. Vertical binning in TDI Mode should only be used if your web's shaft encoder provides a reduced ratio of pulses to match web speed.

Syntax: **`sbv`** ***`i`***

Syntax Elements: **`i`**

Vertical binning value.

Available values are **`1`** (factory setting, no binning), **`2`**, or **`4`**.

Notes:

- For optimal flat field correction, you should rerun the **`ccf`** and **`cpa`** commands after changing binning values.
- Increasing the vertical binning decreases the maximum allowable line rate. For internal exposure mode, **`sem 7`**, the frame is clipped to the maximum allowable and the camera sends a warning. For external exposure mode, **`sem 3`**, a new camera frame rate may be required to avoid ignored syncs.
- Command **`sdv`** set to default (**`1`**).

Example: **`sbv 2`**

Setting Vertical Digital Binning

Syntax: Increases the vertical pixel pitch and light sensitivity by decreasing vertical resolution. Vertical binning in TDI Mode should only be used if your web's shaft encoder provides a reduced ratio of pulses to match web speed.

Syntax: **sdv *i***

Syntax Elements: **i**

Vertical digital binning value.

Available values are **1** (factory setting, no binning), **2**, or **4**.

Notes:

- For optimal flat field correction, you should rerun the **ccf** and **cpa** commands after changing binning values.
- Increasing the vertical binning decreases the maximum allowable line rate. For internal exposure mode, **sem 7**, the frame is clipped to the maximum allowable and the camera sends a warning. For external exposure mode, **sem 3**, a new camera frame rate may be required to avoid ignored syncs.
- Command **sbv** set to default (**1**).
- Not available in area mode.

Example: **sdv 2**

Exposure Mode and Line/Frame Rate

How to Set Exposure Mode and Line/Frame Rate

You have a choice of operating the camera in one of two exposure modes. Depending on your mode of operation, the camera's line/ frame rate (synchronization) can be generated internally through the software command **ssf** or set externally with an EXSYNC signal (CC1). When operating in TDI Mode, it is important that the line rate used matches the web speed. Failure to match the web speed will result in smearing.

To select how you want the camera's line/frame rate to be generated:

1. You must first set the camera's exposure mode using the **sem** command.
2. Next, if using mode 7, use the command **ssf** to set the line/ frame rate.

Setting the Exposure Mode

Purpose:	Sets the camera's exposure mode allowing you to control your sync and line/ frame rate generation.
Syntax:	**sem *m***
Syntax Elements:	**m** Exposure mode to use. Factory setting is **7**.
Notes:	• To obtain the current value of the exposure mode, use the command **gcp** or **get sem**. • When setting the camera to external signal modes, EXSYNC must be supplied. • Refer to Setting Frame Rate for more information on how to operate your camera in TDI or Area Mode. • Exposure Modes are saved separately for TDI Mode and Area Mode. Refer to Saving and Restoring Settings for more information on how to save camera settings.
Related Commands:	**ssf**
Example:	**sem 3**

Table 7: Exposure Modes

Mode	SYNC	Programmable Frame Rate ↓	Programmable Exposure Time ↓	Description
3	External	No	No	Maximum exposure time with no charge reset.
7	Internal	Yes	No	Internal sync, maximum exposure time with no charge reset.

Exposure Modes in Detail

Mode 3: External Trigger, Maximum Exposure Time

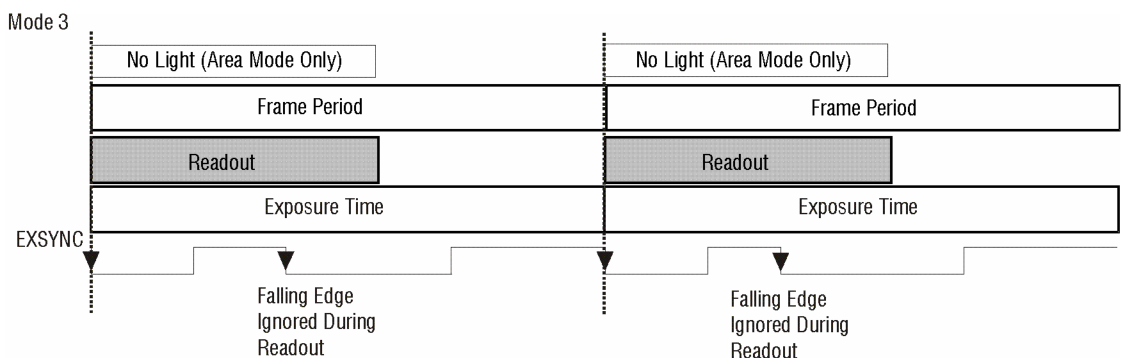


Figure 12: Mode 3 Timing

Mode 7: Internal Frame Rate, Maximum Exposure Time

In this mode, the frame rate is set internally using the **`ssf`** command with a maximum exposure time.

Note: In TDI mode the frame period equals the line period.

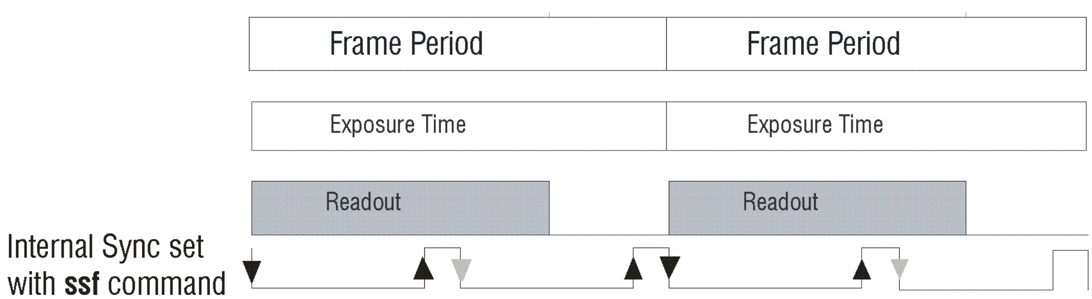


Figure 13: Mode 7 Camera Timing

Setting Frame Rate

Purpose:	Sets the camera's frame rate in Hz. Camera must be operating in exposure mode 7.
Syntax:	**`ssf i`**
Syntax Elements:	**`i`** Set the frame rate to a value from: TDI : 1-34246 Area : 1-130 Value rounded up/ down as required. The maximum line/ frame rate is affected by horizontal and vertical binning factors, throughput setting, Camera Link mode, and number of CCD integration stages.
Notes:	If you enter a frame rate frequency outside of the range displayed on the help screen, an error message is returned and the frame rate remains unchanged. With internal exposure mode, **`sem 7`**, the camera automatically clips the frame rate after binning or the camera link mode if the sync frequency is greater than the allowable maximum. The camera does not automatically change the frame rate after you change the stage selection value. To return the camera's frame rate, use the command **`gcp`** or **`get ssf`**.
Related Commands:	**`sem`**
Example:	**`ssf 10000`**

Maximum Line Rate Calculations

The maximum line rate in the camera is limited by either the Camera Link row time or the sensor row line time. The following calculations are used to determine the maximum line rate.

Variables for calculations:

- SOT = 80 | 160 | 320 | 640
- CLM = 2(3) | 15(16) | 21
- SBH = 1 | 2 | 4
- SDH = 1 | 2 | 4
- SBV = 1 | 2 | 4
- SDV = 1 | 2 | 4
- TDI = 0 | 1
- STG = 16 | 64 | 128 | 192 | 240 | 256

CL_Taps

- If CLM = 2(3) then CL_Taps = 2
- If CLM = 15(16) then CL_Taps = 4
- If CLM = 21 then CL_Taps = 8

Hor_Bin = SBH x SDH

CL_Row_Time = ((8192 / Hor_Bin / CL_Taps) + 8) / ((SOT / CL_Taps) x 10^6)

HN_Row_Time = (3 + ((36 x SBV) + 545)) / 20 x 10^6

HN_Adjust

- If HN_Row_Time > CL_Row_Time then HN_Adjust = 0
- Else HN_Adjust = Ceiling ((CL_Row_Time - HN_Row_Time) x 20 x 10^6)

HN_Rows

- If TDI = 1 then HN_Rows = SDV
- If TDI = 0 then HN_Rows = ((STG / SBV) + 7)

HN_Time = (3 + (((36 x SBV) + 545 + HN_Adjust) x HN_Rows)) / 20 x 10^6

Max_Line_Rate = 1 / HN_Time

Camera Output Format

How to Configure Camera Output

The cameras offer great flexibility when configuring your camera output. Using the **`clm`** command, you determine the camera's Camera Link configuration, number of output taps, and bit depth. Using the **`sot`** command, you determine the camera's output rate. These two commands work together to determine your final camera output configuration.

You can further configure your readout using the **`smm`** command to select the camera's pixel readout direction.

The following tables summarize the possible camera configurations. Refer to the figure below for a description on how to select your camera output.

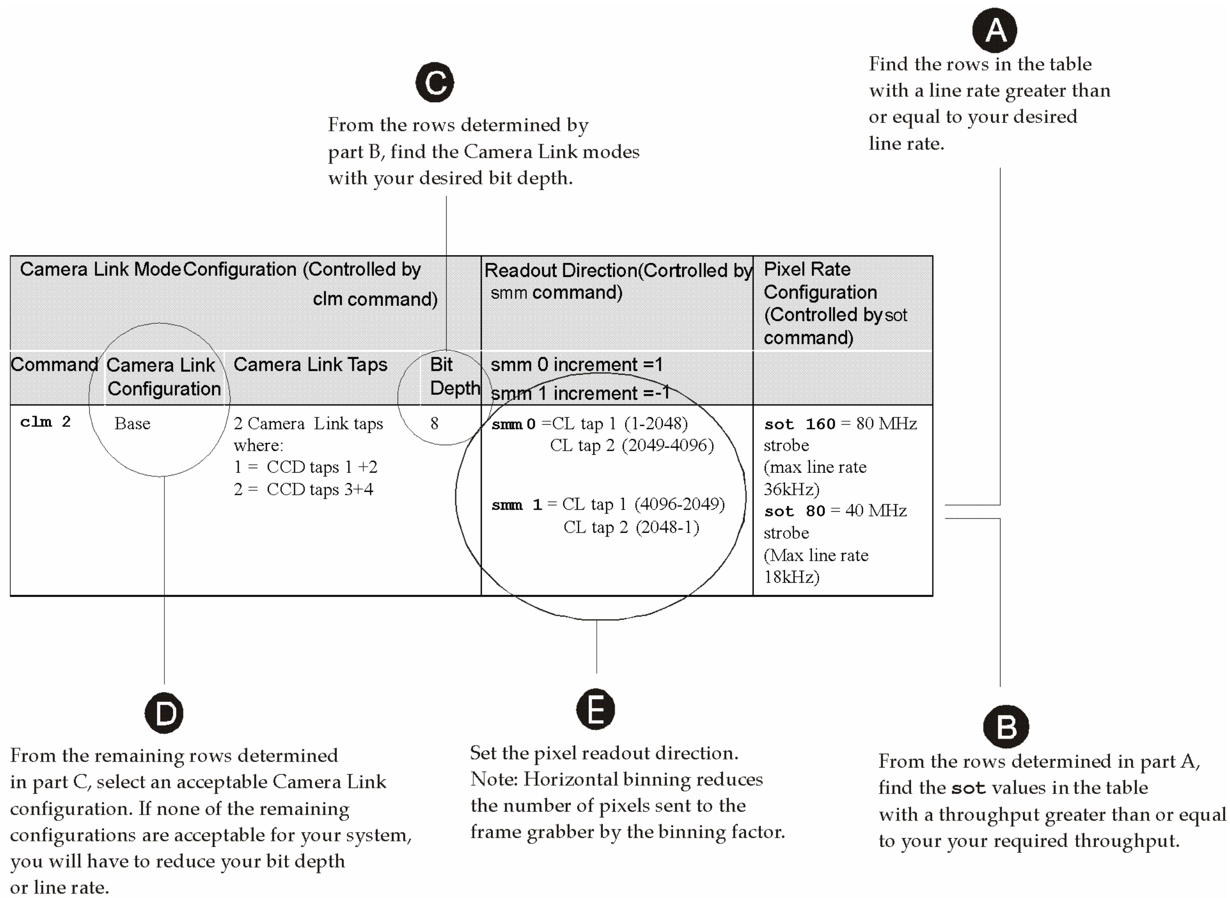


Figure 14: How to Read the Camera Link Tables

Note: In the following tables the Camera Link taps refer to the way the data is configured for output over Camera Link.1.3 Image Sensor

Table 8: HN-80-08k40 Configurations

Camera Link Mode Configuration (Controlled by `clm` command)				Readout Direction (Controlled by `smm` command)	Pixel Rate Configuration (Controlled by `sot` command)
Command	**Camera Link Configuration**	**Camera Link Taps**	**Bit Depth**		
`clm 2`	Base	2 Camera Link taps where: 1 = Odd Pixels 2 = Even Pixels	8	`smm 0` = CL tap 1(1, 3 to 8191) CL tap 2(2, 4 to 8192) `smm 1` = CL tap 1(8192, 8190 to 2) CL tap 2(8191, 8189 to 1)	`sot 80` = 40 MHz strobe `sot 160` = 80 MHz strobe
`clm 3`	Base	2 Camera Link taps where: 1 = Odd Pixels 2 = Even Pixels	12	`smm 0` = CL tap 1(1, 3 to 8191) CL tap 2(2, 4 to 8192) `smm 1` = CL tap 1(8192, 8190 to 2) CL tap 2(8191, 8189 to 1)	`sot 80` = 40 MHz strobe `sot 160` = 80 MHz strobe
`clm 15`	Medium	4 Camera Link taps where: 1 = Every 2nd Odd Pixel 2 = Every 2nd Even Pixel 3 = Every 2nd Odd Pixel 4 = Every 2nd Even Pixel	8	`smm 0` = CL tap 1(1, 5 to 8189) CL tap 2(2, 6 to 8190) CL tap 3(3, 7 to 8191) CL tap 4(4, 8 to 8192) `smm 1` = CL tap 1(8192, 8188 to 4) CL tap 2(8191, 8187 to 3) CL tap 3(8190, 8186 to 2) CL tap 4(8189, 8185 to 1)	`sot 160` = 40 MHz strobe `sot 320` = 80 MHz strobe
`clm 16`	Medium	4 Camera Link taps where: 1 = Every 2nd Odd Pixel 2 = Every 2nd Even Pixel 3 = Every 2nd Odd Pixel 4 = Every 2nd Even Pixel	12	`smm 0` = CL tap 1(1, 5 to 8189) CL tap 2(2, 6 to 8190) CL tap 3(3, 7 to 8191) CL tap 4(4, 8 to 8192) `smm 1` = CL tap 1(8192, 8188 to 4) CL tap 2(8191, 8187 to 3) CL tap 3(8190, 8186 to 2)	`sot 160` = 40 MHz strobe `sot 320` = 80 MHz strobe

Camera Link Mode Configuration (Controlled by `clm` command)				Readout Direction (Controlled by `smm` command)	Pixel Rate Configuration (Controlled by `sot` command)
Command	Camera Link Configuration	Camera Link Taps	Bit Depth		
				CL tap 4(8189, 8185 to 1)	
`clm 21`	Full	8 Camera Link taps where: 1 = Every 4th Odd Pixel 2 = Every 4th Even Pixel 3 = Every 4th Odd Pixel 4 = Every 4th Even Pixel 1 = Every 4th Odd Pixel 2 = Every 4th Even Pixel 3 = Every 4th Odd Pixel 4 = Every 4th Even Pixel	8	**`smm 0`** = CL tap 1(1, 9 to 8185) CL tap 2(2, 10 to 8186) CL tap 3(3, 11 to 8187) CL tap 4(4, 12 to 8188) CL tap 5(5, 13 to 8189) CL tap 6(6, 14 to 8190) CL tap 7(7, 15 to 8191) CL tap 8(8, 16 to 8192) **`smm 1`** = CL tap 1(8192, 8184 to 8) CL tap 2(8191, 8183 to 7) CL tap 3(8190, 8182 to 6) CL tap 4(8189, 8181 to 5) CL tap 5(8188, 8180 to 4) CL tap 6(8187, 8179 to 3) CL tap 7(8186, 8178 to 2) CL tap 8(8185, 8177 to 1)	**`sot 320`** = 40 MHz strobe (max line rate 18814Hz) **`sot 640`** = 80 MHz strobe (max line rate 34305Hz)

Setting the Camera Link Mode

Purpose:	Sets the camera's Camera Link configuration, number of Camera Link taps and data bit depth. Refer to the tables on the previous pages to determine which configurations are valid for your camera model and how this command relates to other camera configuration commands.
Syntax:	**`clm m`**
Syntax Elements:	***m*** Output mode to use: **2**: Base configuration, 2 taps, 8 bit output **3**: Base configuration, 2 taps, 12 bit output **15**: Medium configuration, 4 taps, 8 bit output **16**: Medium configuration, 4 taps, 12 bit output **21**: Full configuration, 8 taps, 8 bit output
Notes:	• When you change the Camera Link mode (**`clm`** command), the camera changes to the maximum **`sot`** throughput (pixels/ sec) for the entered mode. If the current throughput is too slow or too fast for the current Camera Link mode, the camera will automatically adjust the sync frequency value and will return a warning message that a related parameter was adjusted. • To obtain the current Camera Link mode, use the command **`gcp`** or **`get clm`**. • The bit patterns are defined by the Teledyne DALSA Camera Link Roadmap available here, Teledyne DALSA application notes.
Related Commands	**`sot`**
Example:	**`clm 15`**

Setting the Camera Throughput

Purpose:	Works in conjunction with the **`clm`** command (see previous) and determines the throughput of the camera. Refer to the tables in How to Configure Camera Output to determine which configurations are valid for your camera model and how this command relates to other camera configuration commands.
Syntax:	**`sot m`**
Syntax Elements:	***m*** Output throughput. Allowable values are: **80** = 2 taps at 40MHz **160** = 2 taps at 80MHz or 4 taps at 40MHz **320** = 4 taps at 80MHz or 8 taps at 40MHz **640** = 8 taps at 80MHz
Notes:	Throughput is calculated as: *Throughput = (Number of Camera Link Taps) x (Camera Link Pixel Rate in MHz)* • To obtain the throughput setting, use the command **`gcp`** or **`get clm`**. • Throughput values are clipped if the camera is unable to maintain the current throughput setting and a warning message is displayed.
Related Commands	**`clm`**
Example:	**`sot 160`**

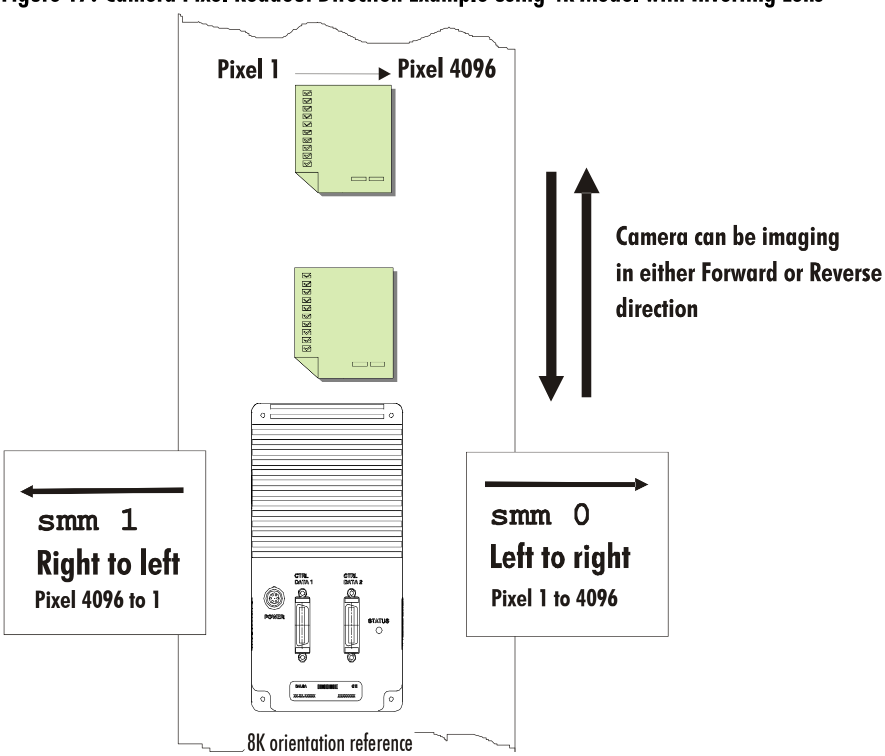
Setting the Pixel Readout Direction

Purpose:	Sets the tap readout from left to right or from right to left. This command is useful if the camera must be mounted upside down.
Syntax:	**`smm i`**
Syntax Elements:	***`i`*** Readout direction. Allowable values are: `0` = All pixels are read out from left to right. `1` = All pixels are read out from right to left.
Notes:	• To obtain the current readout direction, use the command **`gcp`** or **`get smm`**. • This command is available in both TDI and Area Mode. • Refer to the following figures and tables for an explanation of pixel readout and mirror direction. • Refer to [Image Sensor](#) for sensor architecture diagrams that illustrate sensor readout direction.

Figure 15: Left to Right Readout (smm 0) Forward Direction Example Output

Figure 16: Right to Left Readout (smm 1) Forward Direction Example Output

Figure 17: Camera Pixel Readout Direction Example using 4k Model with Inverting Lens



Setting a Region of Interest

Purpose:	Sets the pixel range used to collect the end-of-line statistics and sets the region of pixels used in the **ccg**, **cpa**, **gl**, **gla**, and **ccf** commands. In most applications, the field of view exceeds the required object size and these extraneous areas should be ignored. It is recommended that you set the region of interest a few pixels inside the actual useable image.
Syntax:	**roi x1 y1 x2 y2**
Syntax Elements:	**x1** Column start number. Must be less than or equal to the column end number in a range from **1** to (column resolution – 1). ***y1*** Row start number. Must be less than or equal to the row end number in a range from **1** to (row end number – 1) except in TDI Mode where ***y1*** must be **1**. **x2** Column end number. Must be greater than or equal to the column start number in a range from **2** to column resolution. ***y2*** Row end number. Must be greater than or equal to the row start number in a range from **2** to number of stages except in TDI Mode where ***y2*** must be **1**.
Notes:	• If you are using binning, the start pixel is rounded down to the beginning of binned area and end pixel is rounded up to the end of the binned area. • In Area Mode, the **roi** must be within the stage. If the requested **roi** is above the stage, the **roi** rows will be clipped. The start and end rows will be clipped to the stage selection if necessary. A “clipped to max” warning message is returned.
Related Commands	**ccg**, **cpa**, **gl**, **gla**, **ccf**
Example:	**roi 10 1 50 1 (TDI Mode)**

Digital Signal Processing Chain

Processing Chain Overview and Description

The following diagram shows a simplified block diagram of the camera’s digital processing chain.

The digital processing chain contains the FPN correction, the digital gain, the PRNU correction, the background subtract, and the system gain and background addition. All of these elements are user programmable.

Notes:

- FPN and PRNU correction is not available when operating the camera in Area Mode. For details on how to switch camera operation modes, refer to Setting a Region of Interest.
- The following user settings are stored separately for forward and reverse direction: digital gain, digital offset, and background subtract. They are saved using the **wus** command.
- FPN and PRNU coefficients are stored separately for forward and reverse direction. To save the current PRNU coefficients, use the command **wpc**. To save the current FPN coefficients, use the command **wfc**. Settings are saved for the current direction only.

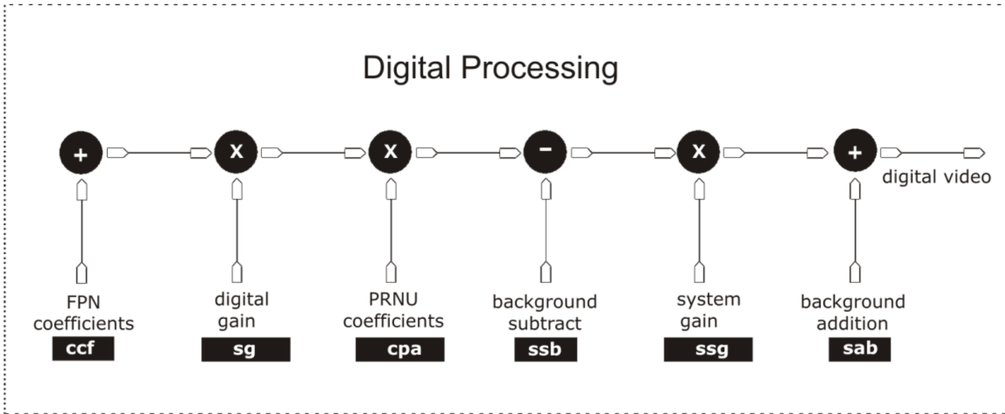


Figure 18: Signal Processing Chain

Digital Processing

1. Fixed pattern noise (FPN) calibration (calculated using the **ccf** command) is used to subtract away individual pixel dark current and dark offset.
2. Digital gain has 3 methods for adjusting the camera digital gain. The **ccg** command adjusts the digital gain for a gain target. The **sg** command allows the user to adjust the gain in dB. The **sg** command does not have a target component in the command algorithm. The digital gain also has a gain component from the PRNU calculation.
3. Photo-Response Non-Uniformity (PRNU) coefficients are used to correct the difference in responsivity of individual pixels (i.e. given the same amount of light different pixels will charge up at different rates) and the change in light intensity across the image either because of the light source or due to optical aberrations (e.g. there may be more light in the center of the image). PRNU coefficients are multipliers and are defined to be of a value greater than or equal to 1. This ensures that all pixels will saturate together. When using PRNU correction, it is important that the A/ D offset and Fixed Pattern Noise (FPN) or per pixel offsets are subtracted prior to the multiplication by the PRNU coefficient. The subtraction of these 2 components ensure that the video supplied to the PRNU multiplier is nominally zero and zero multiplied by anything is still zero resulting in no PRNU coefficient induced FPN. If the offset is not subtracted from the video then there will be artifacts in the video at low light caused by the multiplication of the offset value by the PRNU coefficients.
4. Background subtract (**ssb** command), system gain (**ssg** command), and background addition (**sab**) are used to increase image contrast after FPN and PRNU calibration. It is useful for systems that process 8-bit data but want to take advantage of the camera's 14-bit digital processing chain. For example, if you find that your image is consistently between 128 and 255 DN (8-bit), you can subtract off 128 (**ssb 2048**) and then multiply by 2 (**ssg 4096**) to get an output range from 0 to 255.

Setting the Camera Gain

Calibrating Camera Gain

Purpose: Instead of manually setting the digital gain to a specific value, the camera can determine appropriate gain values. This command calculates and sets the digital gain.

Syntax: **ccg i**

Syntax Elements: **i**

Calculation target value in a range from **4096** to **16064** DN (14 bit LSB).

Notes:

- The algorithm calculates the gain of the 8h tap to set the tap mean to the user target. For adjacent tap 7, the mean of the last 16 pixels are gained to match the mean of the first 16 pixels of tap 8. This seam matching continues to tap 1. For adjacent tap 9, the mean of the first 16 pixels are gained to match the mean of the last 16 pixels of tap 8. This seam matching continues to tap 16.
- To use this command, the CCD shift direction (**scd**) should be set to forward (**0**) or reverse (**1**).

Example: **ccg 12800**

Setting Digital Gain

Purpose: This command sets the digital gain.

Syntax: **sg f**

Syntax Elements: **f**

Gain applied to all taps: -20 dB to +20 dB.

Notes: To use this command, the CCD shift direction (**scd**) should be set to forward (**0**) or reverse (**1**).

Example: **sg 10**

Updating the Gain Reference

Purpose: Sets the current gain setting to be the 0 dB point. This is useful after tap gain matching allowing you to change the gain on all taps by the same amount.

Syntax: **ugr**

Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction)

Flat Field Correction Overview

This camera has the ability to calculate correction coefficients in order to remove non-uniformity in the image when operating in TDI Mode. This video correction operates on a pixel-by-pixel basis and implements a two point correction for each pixel. This correction can reduce or eliminate image distortion caused by the following factors:

- Fixed Pattern Noise (FPN)
- Photo Response Non Uniformity (PRNU)
- Lens and light source non-uniformity

Correction is implemented such that for each pixel:

V_{output} =[(V_{input} - FPN(pixel) - digital offset) * PRNU(pixel) – Background Subtract] x System Gain

where	V_{output}	=	digital output pixel value
	V_{input}	=	digital input pixel value from the CCD
	PRNU(pixel)	=	PRNU correction coefficient for this pixel
	FPN(pixel)	=	FPN correction coefficient for this pixel
	Background Subtract	=	background subtract value
	System Gain	=	digital gain value

The algorithm is performed in two steps. The fixed offset (FPN) is determined first by performing a calculation without any light. This calibration determines exactly how much offset to subtract per pixel in order to obtain flat output when the CCD is not exposed.

The white light calibration is performed next to determine the multiplication factors required to bring each pixel to the required value (target) for flat, white output. Video output is set slightly above the brightest pixel (depending on offset subtracted).

Flat Field Correction Restrictions

It is important to do the FPN correction first. Results of the FPN correction are used in the PRNU procedure. We recommend that you repeat the correction when a temperature change greater than 10°C occurs or if you change the gain, integration time, binning, or number of integration stages.

PRNU correction requires a clean, white reference. The quality of this reference is important for proper calibration. White paper is often not sufficient because the grain in the white paper will distort the correction. White plastic or white ceramic will lead to better balancing.

For best results, ensure that:

1. 60 Hz ambient light flicker is sufficiently low not to affect camera performance and calibration results.
2. For best results, the gain should be adjusted for the expected operating conditions and the ratio of the brightest to darkest pixel in a tap should be less than 3 to 1 where:

$$3 > \frac{\text{Brightest Pixel (per tap)}}{\text{Darkest Pixel (per tap)}}$$

3. The camera is capable of operating under a range of 8 to 1, but will clip values larger than this ratio.

4. The brightest pixel should be slightly below the target output.
5. When 6.25% of pixels from a single row within the region of interest are clipped, flat field correction results may be inaccurate.
6. Correction results are valid only for the current stage selection. If you change the number of stages, it is recommended that you recalculate your coefficients.
7. Correction results are valid only for the current gain and offset values. If you change these values, it is recommended that you recalculate your coefficients.

Note: If your illumination or white reference does not extend the full field of view of the camera, the camera will send a warning.

How to Perform Flat Field Correction

1
Setup the camera operating environment (ie. Line rate, CCD Shift Direction, exposure, offset, gain, etc)

Select the User Set (`ssn 1`, `2`, `3` or `4`)

Digital Offset and gain. Background subtract values should be set to zero. (`ssb 0`, `sab 0`, `ssg 0`)

NOTE:
Items highlighted in GREY are not necessary to perform, unless you require doing so.

Steps 1, 4 and 5 are usually only needed to be performed.

2
Set the calibration sample size using the command `css`. (Optional, since the camera defaults to 4096)

3
Set the region of interest (`roi`) to include all of the images pixels of importance using the command `roi x1 y1 x2 y2`.

4
Perform FPN correction. FPN correction should be performed before PRNU correction.

Repeat FPN correction when a temperature change greater then 10°C occurs OR when there is a significant change in integration time or gain.

1. Stop all light from entering the camera. (Tip: cover lens with a lens cap)
2. Verify the output signal level is at dark by issuing the command `gl` or `gla` (or by viewing a line profile/ histogram of the output.)
3. Issue the command `ccf`. The camera will respond with OK> if no errors occur. FPN correction automatically calibrates the FPN coefficients.
4. After the correction is complete, save the settings by issuing a `wfc` command. (Note that Forward and Reverse direction settings are stored separately and coefficients must be saved before switching directions)

5
Perform PRNU correction

Perform PRNU correction next to determine the multiplication factors (and automatic gain settings for each tap) required to bring each pixel to the required value (balance target) for a flat white output.

1. Place a white reference in front of the camera. (remove lens cap if needed)
2. Issue the command `cpa 2 i` (or `cpa 4 i` if using `roi`), where i is equal to or greater than the maximum pixel value in the image. The camera will respond with OK> if no errors occur.
3. After the correction is complete, save the settings by issuing a `wpc` command. (Note that Forward and Reverse direction settings are stored separately and coefficients must be saved before switching directions)
4. Issue the command `wus` to save all User Settings.

A few notes:

A. Repeat the above steps 3-5 for any CCD shift direction change. (i.e. if the above was performed in FORWARD direction, repeat for REVERSE direction.
B. Always ensure what User Set (`ssn 1`, `ssn 2`, `ssn 3`, `ssn 4`) you are in when performing calibration. When the `wfc`, `wpc` and `wus` commands are performed, this saves all FPN and PRNU coefficients and User settings into that set.
    a. The last User Set (`ssn)` used in the camera will be the same set loaded into the camera during a power cycle.
    b. You can view what User Set you are in via the GCP screen.
    c. Set 0, `ssn 0` is the factory calibration set. It cannot be overwritten by the User.
C. Remember that the `cpa` integer "I" is in 14 bit format. (To set an 8 bit value, multiply this by 64 to get the proper 14 bit value.) (For example if the camera is in 8 bit mode and you want a target value of 200DN, the "I" integer for CPA would be 200x64=12800. So, sending `cpa 2 12800` would give you a target value of 200DN.)
D. The `CPA` command will automatically adjust all tap gain values. The new gains will be displayed in the GCP screen. (ie. If you selected a gain of 5, `sg 0 5` before performing the `CPA 2` command, depending on the automatic gain adjustment, this value may now be different.)

Performing FPN Correction

Syntax: Performs FPN correction and eliminates FPN noise by subtracting away individual pixel dark current. For a complete description on how to use this command, see the Flat Field Correction Overview.

Syntax: **ccf**

Notes:

- Before performing this command, stop all light from entering the camera. (Tip: cover lens with a lens cap.)
- Perform FPN correction before PRNU correction.
- The **ccf** command is not available when the CCD direction is externally controlled (**scd 2**) (see Direction Control). Direction control must be stable while the camera is calculating coefficients.
- Available in TDI Mode only.
- Save coefficients before changing directions, changing operating mode, or powering off.

Related Commands: **cpa**

Example: **ccf**

Setting a Pixel's FPN Coefficient

Purpose: Sets an individual pixel's FPN coefficient.

Syntax **sfc x i**

Syntax Elements: ***x***

The pixel number from 1 to sensor pixel count.

i

Coefficient value in a range from 0-511 (12-bit LSB).

Notes:

- Available in TDI Mode only.

Example: **sfc 10 50**

Returning FPN Coefficients

Purpose: Returns a pixel's FPN coefficient value in DN (12-bit LSB)

Syntax: **gfc *i***

Syntax Elements: ***i***

The pixel number to read in a range from 1 to sensor pixel count.

Notes:

- Available in TDI Mode only.

Example: **gfc 10**

Performing PRNU to a user entered value

Purpose: Performs PRNU calibration to user entered value and eliminates the difference in responsivity between the most and least sensitive pixel creating a uniform response to light. Using this command, you must provide a calibration target.

Executing these algorithms causes the **ssb, sag and sab** commands to be set to 0 (no background addition or subtraction, and unity system gain) and the **ssg** command to 4096 (unity digital gain).

Syntax: **cpa m i**

Syntax Elements: ***m***

PRNU calibration algorithm to use:

2 = Calculates the PRNU coefficients using the entered target value as shown below:

$$\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}_i) - (\text{FPN}_i + \text{analog DC})}$$

4 = Same calculation above, only in ROI.

The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. It is important that the target value (set with the next parameter) is set to be at least equal to the highest pixel across all cameras so that all pixels can reach the highest pixel value during calibration.

i

Peak target value in a range from 4096 DN to 16220 DN. The target value must be greater than the current peak output value.

Notes:

- Calibrate FPN before calibrating PRNU. If you are not performing FPN calibration then issue the **rpc** (reset pixel coefficients) command.

Example: **cpa 2 16000**

Setting a Pixel's PRNU Coefficient

Purpose: Sets an individual pixel's PRNU coefficient.

Syntax: ***spc i1 i2***

Syntax Elements: ***i1***

The pixel number from 1 to sensor pixel count.

i2

Coefficient value in a range from 0 to 61440 where:

$$\text{prnu coefficient} = 1 + \frac{i}{4096}$$

Reading the PRNU Coefficient

Purpose: Read the PRNU coefficient.

Syntax: ***gpc x***

Syntax Elements: ***x***

x = pixel number to read in a range of 1 to 8192.

Resetting the Pixel Coefficients

Purpose: Resets the pixel coefficients to a value of 0.

Syntax: ***rpc***

Digital Signal Processing

Subtracting Background

Purpose: Use the background subtract command after performing flat field correction if you want to improve your image in a low contrast scene. You should try to make your darkest pixel in the scene equal to zero.

Sytax **ssb i**

Syntax Elements: **i**

Subtracted value in a range in DN from 0 to 16383 (14 bit LSB).

Notes:

- See the following section for details on the **ssg** command.

Related Commands	**`ssg`**
Example	**`ssb 500`**

Setting Digital Gain

Purpose: Improves signal output swing after a background subtract. When subtracting a digital value from the digital video signal, using the **`ssb`** command, the output can no longer reach its maximum. Use the this command to correct for this where:

$$\text{ssg value} = \frac{\text{max output value}}{\text{max output value - ssb value}}$$

Syntax: **`ssg i`**

Syntax Elements: **`i`**

Gain setting. The gain ranges are 0 to 61438. The digital video values are multiplied by this value where:

$$\text{System Gain} = 1 + \frac{i}{4096}$$

Notes:

- Use this command in conjunction with the **`ssb`** command (described above).

Related Commands: **`ssb`**

Example: **`ssg 4500`**

Adding Background

Purpose: Use the background addition command after performing flat field correction to inject a DC value to measure dark random noise

Sytax **`sab i`**

Syntax Elements: **`i`**

Added value in a range in DN from 0 to 16383 (14 bit LSB).

Notes:

Related Commands

Example **`sab 320`**

Saving and Restoring Settings

Saving and Restoring Factory and User Settings

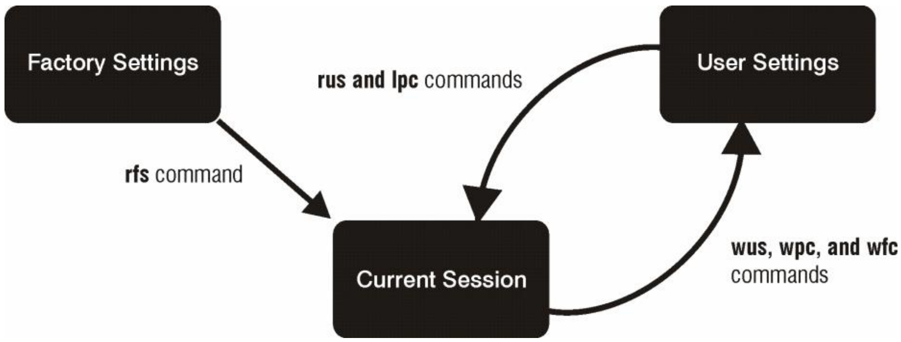


Figure 19: Saving and Restoring Overview

Factory Settings

You can restore the original factory settings, including the factory calibrated pixel coefficient set, at any time using the command **`rfs`**.

User Settings

There are two main sets of user settings: Area Mode user settings and TDI Mode user settings. After issuing the user settings save command, **`wus`**, settings are saved depending on which mode the camera is operating in when the command is issued. Also, when operating in TDI Mode, analog gain and offset, digital gain and offset, and background subtract values are saved as distinct values for Forward and Reverse directions. In other words, you can program the camera to operate with an analog gain value of +5db in Forward direction and an analog gain value of +3db in Reverse direction. Forward and Reverse direction settings are saved simultaneously with the **`wus`** command.

Note: When you switch directions, the settings saved for that direction are automatically loaded.

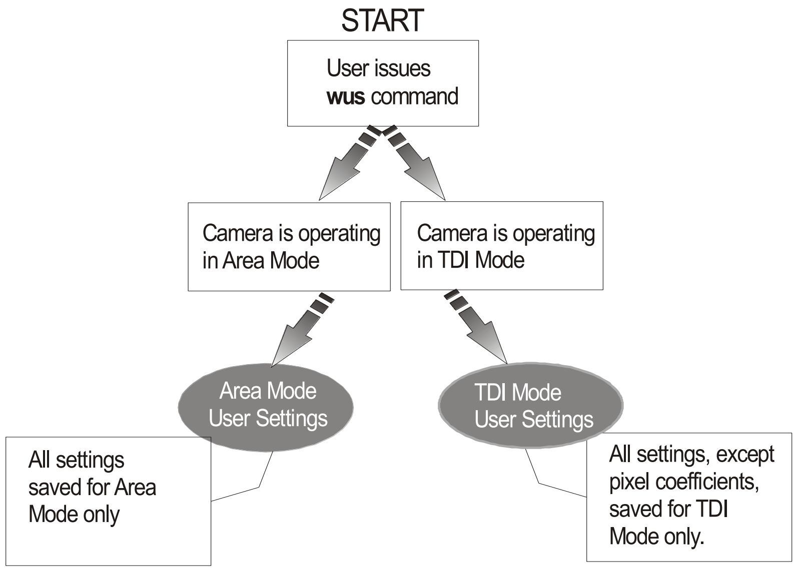


Figure 20: How User Settings are Stored in the HN-xx Cameras after issuing the wus Command

You can save or restore your user settings to non-volatile memory using the following commands.

- To save all current user settings to EEPROM for the current mode for both TDI shift directions, use the command **wus**. The camera will automatically restore the saved user settings when powered up.

WARNING: While settings are being written to nonvolatile memory, do not power down camera or camera memory may be corrupted.

- To restore the last saved user settings for the current mode, use the command **rus**.

Current Session Settings

These are the current operating settings of your camera. These settings are stored in the camera's volatile memory and will not be restored once you power down your camera. To save these settings for reuse at power up, use the command **wus**. Settings are saved for the current operating mode (TDI or Area) only.

Saves the Current User Settings

Purpose:	Saves the current user settings for the current direction and set number.
Syntax:	**wus**
Notes:	• Available in TDI or area mode for sets 1 to 4.
Example:	**wus**
See also:	**rus, rfs**

Restores the Saved User Settings

Purpose:	Restores the saved user settings for the current direction and set number.
Syntax:	**rus**
Notes:	• Available in TDI or area mode for sets 1 to 4.
Example:	**rus**
See also:	**wus, rfs**

Restores the Factory User Settings

Purpose:	Restores the factory user settings for the current direction to the current set number.
Syntax:	**`rfs`**
Notes:	• Available in TDI or area mode for sets 1 to 4.
Example:	**`rfs`**
See also:	**`wus, rus`**

Selecting the Set Number

Purpose:	When saving and loading camera settings, you have a choice of saving up to four different sets and loading from five different sets (four user and one factory). This command determines the set number from where these values are loaded and saved.
Syntax:	**`ssn`**
Syntax Elements:	**`i`**
	`0` = Factory set. Settings can only be loaded from this set.
	`1` - **`4`** = User sets. You can save, or load settings with these sets.
Note:	The camera powers up with the last set saved using this command.
Example:	**`ssn 3`**
Related:	**`rus`**

Saving and Restoring PRNU and FPN Coefficients

Pixel coefficient sets are saved separately for Forward and Reverse direction, depending on which direction the camera is operating in when the **wpc** or **wfc** command is issued. It is important that you save pixel coefficients before switching CCD shift direction or current coefficient values will be lost.

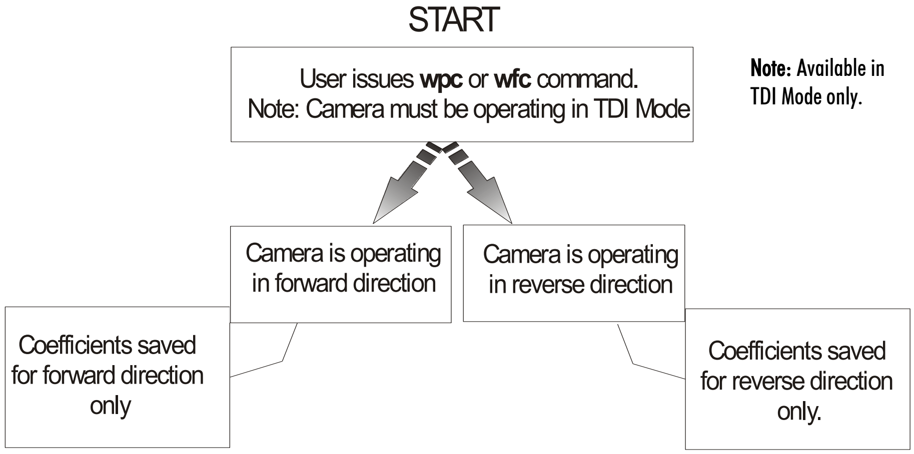


Figure 21: How Pixel Coefficients are saved in the HN-xx Cameras after issuing the wpc or wfc Command

Saving the Current PRNU Coefficients

Purpose:	Saves the current PRNU coefficients for the current direction.
Syntax:	**wpc**
Notes:	• Available in TDI mode only. • Available only when operating the camera in internal direction control (**scd 0** or **1**)
Example:	**wpc**

Saving the Current FPN Coefficients

Purpose:	Saves the current FPN coefficients for the current direction.
Syntax:	**wfc**
Notes:	• Available in TDI mode only. • Available only when operating the camera in internal direction control (**scd 0** or **1**)
Example:	**wfc**

Loading the Current Pixel Coefficients

Purpose:	Loads the current FPN and PRNU coefficients for the current direction.
Syntax:	**lpc**

Rebooting the Camera

The command **rc** reboots the camera. The camera starts up with the last saved settings and the baud rate used before reboot. Previously saved pixel coefficients are also restored.

Diagnostics

Generating a Test Pattern

Purpose:	Generate a test pattern to aid in system debugging. The test patterns are useful for verifying proper timing and connections between the camera and the frame grabber. The following tables show each available test pattern.
Syntax:	**svm** ***i***
Syntax Elements:	***i*** **Svm 0** : Video **Svm 1**: DC DCi = Integer ((i – 1) / 1024) * 24 + 24 Where i = 1 to 8192 **Svm 2**: Horizontal HORi = Modulus (DCi + Modulus (Modulus ((i – 1), 1024), 256), 256) Where i = 1 to 8192 **Svm 3**: Vertical VERi = Modulus (DCi + FR, 256) FR = 1, 2, 3, 4, …, 256 **Svm 4**: Diagonal DIAGi = Modulus ((HORi + FR), 256) Where i = 1 to 8192, FR = 1, 2, 3, 4, …, 256
Notes:	• When returning to video (**svm 0**) after viewing a test pattern, the camera restores the saved user settings for set subtract background (**ssb**), and set system digital gain (**ssg**).
Example:	**svm 2**

Returning Video Information

The camera's microcontroller has the ability to read video data when operating the camera in TDI Mode. This functionality can be used to verify camera operation and to perform basic testing without having to connect the camera to a frame grabber. This information is also used for collecting line statistics for calibrating the camera.

Returning a Single Line of Video

Purpose: Returns a complete line of video (without pixel coefficients or test pattern) displaying one pixel value after another. It also displays the minimum, maximum, and mean value of the line sampled within the region of interest (the region of interest command is explained in Setting a Region of Interest).

Use the **gl** command, or the following **gla** command, to ensure the proper video input range into the processing chain before executing any pixel calibration commands.

Syntax: **gl x1 x2**

Syntax Elements: ***x1***

Column start number. Must be less than the column end number in a range from **1** to (**column resolution - 1**).

x2

Column end number. Must be greater than the column start number in a range from **2** to sensor resolution.

Notes:

- If **x2** $\leq$ **x1** then **x2** is forced to be **x1**.
- Analog gain, analog offset, digital offset, background subtract, and digital system gain are applied to the data. FPN and PRNU coefficients are not included in the data.
- Values returned are in 12 bit DN.
- Available in TDI Mode only.

Related Commands **roi**

Example: **gl 10 20**

Returning Averaged Lines of Video

Setting the Number of Lines to Sample

Purpose: Sets the number of lines to sample when using the **gla** command or for pixel coefficient calculations.

Syntax: **css *i***

Syntax Elements: **i**

Number of lines to sample. Allowable values are **1 / 1024 (factory setting) / 2048 / 4096**.

Notes:

- To return the current setting, use the **gcp** command.

Related Commands: **gla**

Example: **css 1024**

Returning the Average of Multiple Lines of Video

Purpose: Returns the average for multiple lines of video data (without pixel coefficients or test pattern). The number of lines to sample is set and adjusted by the **css** command. The camera displays the Min., Max., and Mean statistics for the pixels in the region of interest (the region of interest command is explained in Setting a Region of Interest).

Syntax: **gla x1 x2**

Syntax Elements: ***x1***

Column start number. Must be less than the column end number in a range from **1** to (**column resolution - 1**).

x2

Column end number. Must be greater than the column start number in a range from **2** to column resolution.

Notes:	• If **x2** $\leq$ **x1** then **x2** is forced to be **x1**. • Analog gain, analog offset, digital offset, background subtract, and digital system gain are applied to the data. FPN and PRNU coefficients are not included in the data. • Values returned are in 12 bit DN. • Available in TDI Mode only.
Related Commands:	css, roi
Example:	**gla 10 20**

Temperature Measurement

The temperature of the camera can be determined by using the **vt** command. This command will return the internal chip temperature in degrees Celsius. For proper operation, this value should not exceed 75°C.

Note: If the camera reaches 75°C, the camera **will shut down and the LED will flash red**. If this occurs, the camera **must be rebooted** using the command, **rc** or can be powered down manually. You will have to correct the temperature problem or the camera will shut down again.

Voltage Measurement

The command **vv** displays the camera's input voltage. Note that the voltage measurement feature of the camera provides only approximate results (typically within 10%). The measurement should not be used to set the applied voltage to the camera but only used as a test to isolate gross problems with the supply voltage.

Camera Frequency Measurement

Purpose:	Returns the frequency for the requested Camera Link control signal
Syntax:	**gsf m**
Syntax Elements:	
	Camera Link control signal to measure: 1: CC1 (EXSYNC) 3: Direction
Example:	**gsf**

Returning Camera Settings

Returning All Camera Settings with the Camera Parameter Screen

The camera parameter (**gcp**) screen returns all of the camera's current settings.

To read all current camera settings, use the command:

Syntax: **gcp**

Table 9: GCP Screen Reference

GCP Screen	Description
CAMERA SETTINGS	

GCP Screen		Description
Camera Model No.:	HN-xx-xxxxx-xx-R	Camera model number.
Sensor Serial No.:	xxxxxxxxx	Sensor serial number.
Firmware Design Rev.:	xx-xx-xxxxx-xx	Firmware design revision number.
CCI Version:	xx-xxx-xxxxx-xx	Camera control information.
FPGA Version:	xx-xx-xxxx-xx	DSP design revision number.
SSN	0	Set Number
Video Mode:	video	Current video mode value set with the **`svm`** command.
Number of Line Samples:	1024	Number of lines sample with the **`gla`** command set with the **`css`** command.
Exposure Mode:	7	Current exposure mode value set with the **`sem`** command.
SYNC Frequency:	5000.00 Hz	Current line rate. Value is set with the **`ssf`** command.
CCD Direction:	internal/ forward	CCD shift direction set with the **`scd`** command.
Mirroring Mode:	0, left to right	Readout direction set with the **`smm`** command.
Analog Horizontal Binning	1	Horizontal binning value set with the **`sbh`** command.
Analog Vertical Binning	1	Vertical binning value set with the **`sbv`** command.
Digital Horizontal Binning		
Digital Vertical Binning		
Stage Selection	96	Number of integration stages set with the **`stg`** command.
TDI Mode:	tdi	Current operating mode, either TDI or Area set with the **`tdi`** command.
Region of Interest:	(1,1) to (8192,1)	Region of interest size set with the **`roi`** command.
Camera Link Mode:	21, Full, 8 taps, 8 bits, no time MUX	Camera Link configuration set with the **`clm`** command.
Output Throughput:	320	Camera throughput value set with the **`sot`** command.
Reference Gain (dB):	0.0 0.0 0.0 0.0	Analog reference gain set with the **`ugr`** command.
System Gain:	0	Digital gain settings set with the **`ssg`** command.

GCP Screen		Description
Background Addition:	0	Background addition settings set with the **sab** command.
Background Subtract:	0	Background subtract settings set with the **ssb** command.

Returning Camera Settings with Get Commands

You can also return individual camera settings by inserting a "**get**" in front of the command that you want to query. If the command has a tap or pixel number parameter, you must also insert the tap number or pixel number that you want to query. To view a help screen listing the following get commands, use the command **gh**.

Appendix A: Error Handling and Command List

Error Handling

The following table lists warning and error messages and provides a description and possible cause. Warning messages are returned when the camera cannot meet the full value of the request; error messages are returned when the camera is unable to complete the request.

Table 10: Warning and Error Messages

Warning Messages	
Camera Response	Comment
OK>	Camera executed command
Warning 01: Outside of specification>	Parameter accepted was outside of specified operating range (e.g. gain greater than ±10 dB of factory setting, or SSF below specification).
Warning 02: Clipped to min>	Parameter was clipped to the current operating range. Use GCP or GET to see value used.
Warning 03: Clipped to max>	Parameter was clipped to the current operating range. Use GCP or GET to see value used.
Warning 04: Related parameters adjusted>	Internal operating condition is adjusted to accommodate the entered command. E.g. requesting exposure time longer than line time automatically adjusts the line time to meet the exposure time requirement.
Warning 07: Coefficient may be inaccurate A/ D clipping has occurred>	In the region of interest (ROI) greater than 6.251% single or 1% of averaged pixel values were zero or saturated.
Warning 08: Greater than 1% of coefficients have been clipped	Greater than 1% of FPN or PRNU coefficients have been calculated to be greater than the maximum allowable and so were clipped.
Warning 09: Internal line rate inconsistent with read out time>	Changing this parameter (e.g. vertical binning) has changed read out time and that is greater than the *internal* SYNC

Error Messages	
Camera Response	Comment
Error 01: Internal error xx>	Where xx is a code list below. Only output during power up. Customer should contact Teledyne DALSA customer support.
Error 02: Unrecognized command>	Command is not valid.
Error 03: Incorrect number of parameters>	Too many or too few parameters.
Error 04: Incorrect parameter value>	This response returned for: Alpha received for numeric or visa versa Float where integer expected Not an element of the set of possible values. E.g., Baud Rate Outside the range limit

Error Messages	
Error 05: Command unavailable in this mode>	E.g. SSF when in SEM 3
Error 06: Timeout>	Command not completed in time. E.g. CCF in SEM 3 when no external EXSYNC is present.
Error 07: Camera settings not saved>	Indicates that user settings have been corrupted by turning off the power while executing the WUS command. Must build up new settings from factory and re-save with WUS.
Error 08: Unable to calibrate - tap outside ROI>	Cannot calibrate a tap that is not part of the end of line statistics.
Error 09: The camera's temperature exceeds the specified operating range>	Indicates that the camera has shut itself down to prevent damage from further overheating. (flashing red) Shuts down at internal temperature of 75˚C and will not restart until below 65˚C (equivalent to 50˚C at front plate).
Error 10: FPGA Flash Program Failed	FCS failed either because of communication error or a bad file was sent.

Commands: Quick Reference

As a quick reference, the following table lists all of the camera configuration commands available to the camera user. For detailed information on using these commands, refer to Command Format. Note: This table does not list "get" commands. Refer to Returning Camera Settings for a list of these commands.

Parameters:
t = tap id
i = integer value
f = float
m = member of a set
s = string
x = pixel column number
y = pixel row number

Table 11: Command Quick Reference

Mnemonic	Syntax	Parameters	Description
correction calibrate fpn	**ccf**		Performs FPN calibration and eliminates FPN noise by subtracting away individual pixel dark current.
calculate camera gain	**ccg**	**i**	Calculates the camera **i** = Calibration target value in a range from: **4096** to **16064** DN (14 bit LSB).
camera link mode	**clm**	**m**	Sets the Camera Link configuration, number of Camera Link taps, and data bit depth. **2**: Base configuration, 2 taps, 8 bit output **3**: Base configuration, 2 taps, 12 bit output **15**: Medium configuration, 4 taps, 8 bit output **16**: Medium configuration, 4 taps, 12 bit output **21**: Full configuration, 8 taps, 8 bit output

Mnemonic	Syntax	Parameters	Description
calculate PRNU algorithm	**cpa**	**m i**	Performs PRNU calibration according to the selected algorithm. The first parameter is the algorithm where m is: **2** = Calculates the PRNU coefficients using the entered target value as shown below: $\text{PRNU Coefficient}_i = \dfrac{\text{Target}}{(\text{AVG Pixel Value}_i) - (\text{FPN}_i + \text{analog DC})}$ The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. **4** = Same algorithm as cpa 2 in ROI. **i** = Peak target value in a range from 4096 DN to 16220 DN. The target value must be greater than the current peak output value.
correction set sample	**css**	**m**	Set number of line samples averaged for pixel coefficient calculations or for output of **gla** command. Values: **1/ 1024 / 2048 / 4096 (factory)**.
display pixel coefficients	**dpc**	**xx**	1 – 8192 : 1 - 8192
get camera log	**gcl**		Returns the last 18 commands before the **gcl**
get camera model	**gcm**		Reads the camera model number.
get camera parameters	**gcp**		Reads all of the camera parameters.
get camera serial	**gcs**		Read the camera serial number.
get camera version	**gcv**		Displays the firmware version and FPGA version.
get values	**get**	**s**	Retrieves camera values.
get fpn coeff	**gfc**	**x**	Read the FPN coefficient **x** = pixel number to read in a range from **1** – **8192**.
get help	**gh**		Returns the help screen.
get line	**gl**	**x1 x2**	Gets a line of raw video (no digital processing or test pattern) displaying one pixel value after another and the minimum, maximum, and mean value of the sampled line. **x1** = Pixel start number **x2** = Pixel end number In a range from **1** to 8192.
get line average	**gla**	**x1 x2**	Read the average of line samples. **x1** = Pixel start number **x2** = Pixel end number in a range from **1** – **8192**.
get prnu coeff	**gpc**	**x**	Read the PRNU coefficient. **x** = pixel number to read in a range from **1** – **8192**.
get signal frequency	**gsf**	**m**	Reads the requested Camera Link control frequency: 1 CC1 (EXSYNC) or 3 (Direction).
help	**h**		Display the online help. Refer to section for details.
load pixel coefficients	**lpc**		Loads the current FPN and PRNU coefficients for the current direction.
reset camera	**rc**		Reset the entire camera (reboot). Baud rate is not reset and reboots with the value last used.

Mnemonic	Syntax	Parameters	Description
restore factory settings	**rfs**		Restore the camera's factory settings. FPN and PRNU coefficients reset to 0.
region of interest	**roi**	**x1 y1 x2 y2**	Sets the pixel range affected by the **ccg**, **gl**, **gla**, **ccf**, **cpa** and **ccp** commands. The parameters are the pixel start and end values (**x1** and **x2**) and the column start and end values (**y1** and **y2**) in a range from **1** to **8192**.
reset pixel coeffs	**rpc**		Reset the pixel coefficients to 0.
restore user settings	**rus**		Restore the camera's last saved user settings.
set addition background	**sab**	**i**	Subtract the input value from the output signal. **i** = Added value in a range from **0** to **4096**.
set analog binning horizontal	**sbh**	**m**	Sets the horizontal binning value. Available values are **1**, **2**, **4**.
set analog binning vertical	**sbv**	**m**	Sets the vertical binning value. Available values are **1, 2, 4**.
set ccd direction	**scd**	**i**	Sets the CCD shift direction where: **0 =** Forward TDI shift direction. **1 =** Reverse TDI shift direction. **2 =** Externally controlled direction control via Camera Link control CC3. Available only in TDI Mode
set digital binning horizontal	**sdh**	**m**	Sets the horizontal binning value. Available values are **1**, **2**, **4**.
set digital binning vertical	**sdv**	**m**	Sets the vertical binning value. Available values are **1, 2, 4**.
set exposure mode	**sem**	**m**	Set the exposure mode: **3 =** External SYNC, maximum exposure time **7 =** Internal programmable SYNC, maximum exposure time. Factory setting.
set fpn coeff	**sfc**	**x i**	Set the FPN coefficient. **x** =pixel number within the range **1** to 8192. **i**= FPN value within the range **0** to **8191** (12-bit LSB).
set gain	**sg**	**f**	In a range -20 to +20 DN.
set mirror mode	**smm**	**i**	Set the camera's mirror mode: **0**: Pixels readout left to right (1 to 4096 or 8192) **1**: Pixels readout right to left (8092 or 4096 to 1)
set output throughput	**sot**	**m**	This command works in conjunction with the **clm** command and determines the Camera Link strobe rate. **80 =** 4 taps at 20MHz or 2 taps at 40MHz **160 =** 2 taps at 80MHz or 4 taps at 40MHz **320 =** 4 taps at 80MHz or 8 taps at 40MHz **640 =** 8 taps at 80MHz
set prnu coeff	**spc**	**x i**	Set the PRNU coefficient. **x**=pixel number within the range **1** to 8192. **i**= PRNU value within the range **0** to **61438**.
set prnu range	**spr**	**x1 x2 i**	Set a range of pixel PRNU coefficients **x1**=first pixel number of the range 1 to 8192. **x2**=last pixel number of the range 1 to 8192. **i**=coefficient value in a range from **0** to 61438.
set subtract background	**ssb**	**i**	Subtract the input value from the output signal. **i** = Subtracted value in a range from **0** to 4096.

Mnemonic	Syntax	Parameters	Description
set sync frequency	**ssf**	**f**	Set the frame rate to a value from: TDI: **1-34246** Area: **1-130** Value rounded up/ down as required.
set system gain	**ssg**	**i**	Set the digital gain. **i** = System gain in a range from **0** to **61438**. The digital video values are multiplied by this number.
set set number	**ssn**	**i**	Sets the "set" number from where these values are loaded and saved. **i** = set number in a range from 0 to 4.
stage select	**stg**	**i**	Sets the number of stages. Allowable values are: **16,64, 128, 192, 240, 256**
set video mode	**svm**	**i**	Switch between normal video mode and test patterns: **0 (video) to 4 (test patterns).**
set TDI mode	**tdi**	**i**	Set the camera's operating mode. **0**: Area Mode **1**: TDI Mode Refer to Setting a Region of Interest for details
update gain reference	**ugr**		Changes 0dB gain to equal the current gain value
verify temperature	**vt**		Check the internal temperature of the camera
verify voltage	**vv**		Check the camera's input voltages and return OK or fail
write FPN coefficients	**wfc**		Write all current FPN coefficients to EEROM.
write PRNU coeffs	**wpc**		Write all current PRNU coefficients to EEROM.
write user settings	**wus**		Write all of the user settings to EEROM.

Appendix B: Quick Setup and Image Acquisition

If you are familiar with the operation of Camera Link cameras and have an understanding of imaging fundamentals, the following steps will show you how to quickly set up this camera and begin acquiring images.

1. On Power Up

The camera has been calibrated and configured at the factory to be ready for your evaluation when first powered up. The default conditions are set as follows:

- System gain is set to the lowest value of 0 dB.
- Flat field calibration is *always* active as per the factory calibration environment. However, as this feature is dependent on your light source and lens, flat field calibration in the customer system is recommended for the best performance experience.
- Line rate and exposure time are set to for internal generation by the camera.
- Camera Link mode is set to mode 21, which allows operation of up to 34 KHz line rate.

2. Communicating with the Camera

- The camera is designed to interface with Teledyne DALSA’s three letter command (TLC) interface, which can be accessed using a suitable terminal program such as HyperTerminal™.
- The TLC interface is fixed to 115,200 Baud.
- Enter ‘h’ at any time to get the list of commands from the camera.
- Enter the ‘gcp’ command at any time to get the current setup conditions of the camera.

3. Setting Up Your Optical Configuration

Typically, the first thing you want to do is to evaluate the camera’s image quality under operating conditions similar to those that you are likely to use in your application. In order to do this, take the following steps:

- The illumination, lens magnification, and focus should be set up as per you application.
- Getting the magnification right is best accomplished by setting the object-to-sensor distance. Use the formula *lens focal length x (2 + 1/magnification + magnification)* to calculate this distance. Magnification equals the sensor pixel size (7 µm) / (your object pixel size in um).

- The approximate location of the sensor position is at the first groove in the side of the case, back from the front face as shown in the mechanical illustration.

4. Camera Timing & Control

It is easiest and quickest to evaluate the camera using the internal timing setups for line rate and exposure time.

- Since we recommend starting with Camera Link medium mode, set a suitable line rate less than 20 KHz, using the 'ssf' command.
- The camera is a TDI line scan-type camera and therefore it is important that the synchronization frequency (EXSYNC) is set to provide a sync signal at the equivalent object motion time. Refer to the EXSYNC binning diagrams in this manual for clarification.
- Set your camera direction using the 'scd' command. Refer to the Sensor Shift Direction diagram in this manual for a definition of 'forward' and 'reverse'.

5. Acquiring an Image

You can now begin imaging. Unless you have an application employing lots of light, the image is likely to be too dark.

- Use the system gain to adjust the camera output to achieve the desired response. The system gain range is from 0 dB to 20 dB.
- Once you have a suitable response, you can now focus the lens.
- The image may be darker at the edges due to lens vignetting, but this will be improved once the camera is calibrated.

6. Calibration

The camera is shipped with the calibration accomplished with the following conditions:

Gain set to minimum (sg 0)

Horizontal Binning modes off (sbh 1 or sdh 1)

Line rate at 7500 Hz

However, if the camera is operated under different conditions and in particular at higher gains, with binning modes on, or at a different significantly slower line rate, then the calibration will not be optimum or no longer valid. The calibration in particular is the fixed pattern noise (FPN) which is the variation in pixel response in darkness, and the photo response non-uniformity (PRNU) which is the variation in pixel response with illumination. This calibration is also referred to as "flat field correction". Fortunately, the FPN and PRNU can be recalibrated by the user after new operating conditions are applied. It is highly recommended that the FPN and PRNU correction be re-calibrated if the operating conditions are different than listed above.

FPN Correction

The FPN correction is easy to apply. The basic procedures are to remove all light (or apply a lens cap on the camera) and then issue the ccf command.

PRNU Correction

The PRNU correction is more involved since the key requirement is that the camera be exposed to a uniform illumination with no pattern in the image. The light level should be at the same level over the whole width of the sensor. Then the cpa command is issued. As well, the highest pixel value must not exceed the target value. (The cpa command generates 2 outputs. The first is the per pixel coefficient where all pixels are gained to match the highest pixel. The second is the sensor gain equal to the target divided by the highest pixel value.) Note: Before the micro executes the cpa command all gains are set to 0 dB.

- Calibration is performed using a white reference where your object is normally located.
    - Use a white material that has no texture, such as a non glossy plastic.
    - If you must use white paper, make sure it is moving during the calibration process. If you do not do this, your image will have vertical stripes.

There are two input parameters for the cpa command, the first is the algorithm type and “2” is used to select all 8192 pixels from the CCD. The second parameter is the target light level value which must be entered as a 14 bit number since the ADC is a 14 bit device. If the camera is operating in 8-bit mode (clm 21), and then if the target level is 200 DN 8-bit, then the entered parameter converted to 14-bit is 64x bigger or 200 x 64 = 12800. Enter the command: cpa 2 12800. If the camera is operating with 12-bit data (clm 16), then multiply the target value by 4.

The method then is to adjust the uniform white light level before the calibration is applied to approximately the level desired, for example, set so that the average output is 200 DN 8-bit. Then apply the command cpa 2 12800. The successful result is that the data level across the whole sensor should become 200 DN 8-bit.

When using the camera on a solar cell PL inspection system, the challenge is that the light source used for the PL imaging is not seen by the camera. Therefore, a separate light source will need to be applied and ideally it would be near the operating wavelength (> 1000 nm). To keep the process simple, it might be good enough to instead apply a broad band white light source.

To help remove any pattern in the image, the lens should be de-focused. Since the lens will already be focused for 1000 nm, then with white light (shorter wavelengths) the image will be de-focused. The target needs to be a uniform white surface with a mat or diffusing surface. It is going to require some experimenting to discover how to achieve the best uniform light.

Note that the ccf and cpa need to be applied to both scan directions if you are using both scan directions.

- On completion of the ‘cpa’ command, you should see an image from the camera with very little PRNU at the target level you set.

You are now ready to evaluate the image quality of the camera under your operating conditions.

7. Restoring Factory Calibration: lpc Comand

The calibration coefficients can be saved in the camera in 5 different "sets", numbered from zero to four. The factory calibrations are saved in set zero and you cannot overwrite the "zero" settings. To operate in "set zero" you use the "set set number" or ssn command by typing ssn 0. Next, to restore the factory coefficients, you need the "load pixel coefficients" or lpc command. Unfortunately, this command was not documented in the User's manual you have and this will be updated in the future revisions. The description is as follows:

Loading a Saved Set of Coefficients

Purpose:	Loads a saved set of pixel coefficients for the current direction. A factory calibrated set of coefficients is available.
Syntax:	**`lpc`**
Notes:	• Available in TDI mode only.

To restoring the camera calibration settings, then the following sequence is this (using the "/ / " to add comments):

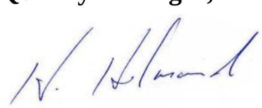
```
ssn 0   // sets the camera set number to the factory set
lpc     // loads the factory coefficients
ssn 1   // sets the user set number
wfc     // saves the fpn coefficients
wpc     // saves the prnu coefficients
```

This sequence should restore your coefficients back to the factory settings.

Note that this restoring process will not restore the factory gain settings, cameralink modes, sync frequency, and any other camera settings you may have changed and then saved using the wus command. These settings are all restored using the rfs command which must be followed by the wus command to make them "remembered" for the next power cycle.

Contact Teledyne DALSA's technical support for further details.

Appendix C: EMC Declaration of Conformity

We,	Teledyne DALSA 605 McMurray Rd., Waterloo, ON CANADA N2V 2E9
declare under sole responsibility, that the product(s):	
	HN-80-08k40
fulfill(s) the requirements of the standard(s)	
EMC:	CISPR-22:1997 EN 50082-1:1997 EN 61000-4-2; +/ - 6kV CD, +/ -8kV AD:1995 EN 61000-4-3; 3V/ m:1996 EN 61000-4-4; 500V, 1100V:1995
This product complies with the requirements of the Low Voltage Directive 73/ 23/ EEC and the EMC Directive 89/ 336/ EEC and carries the CE mark accordingly. The 8k cameras were equipped with the following lens adapter during testing: AC-LA-0109 (Adapter, M72 to Nikon lens).	
Place of Issue	Waterloo, ON, CANADA
Date of Issue	7-September-2012
Name and Signature of authorized person	**Hank Helmond** **Quality Manager, Teledyne DALSA Corp.** 

This Declaration corresponds to EN 45 014.

Appendix D: CCD Handling Instructions

Electrostatic Discharge and the CCD Sensor

Cameras contain charge-coupled device (CCD) image sensors, which are metal oxide semiconductor (MOS) devices and are susceptible to damage from electrostatic discharge (ESD).

Electrostatic charge introduced to the sensor window surface can induce charge buildup on the underside of the window that cannot be readily dissipated by the dry nitrogen gas in the sensor package cavity. When charge buildup occurs, surface-gated photodiodes (SGPDs) may exhibit higher image lag. Some SGPD sensors, such as the IL-P4 and the IT-P4 used in the Piranha2 cameras, may also exhibit a highly non-uniform response when affected by charge buildup, with some pixels displaying a much higher response when the sensor is exposed to uniform illumination. The charge normally dissipates within 24 hours and the sensor returns to normal operation.

WARNING: Charge buildup will affect the camera's flat-field correction calibration. To avoid an erroneous calibration, ensure that you perform flat-field correction only after a charge buildup has dissipated over 24 hours.

Protecting Against Dust, Oil and Scratches

The CCD window is part of the optical path and should be handled like other optical components, with extreme care.

Dust can obscure pixels, producing dark patches on the sensor response. Dust is most visible when the illumination is collimated. The dark patches shift position as the angle of illumination changes. Dust is normally not visible when the sensor is positioned at the exit port of an integrating sphere, where the illumination is diffuse.

Dust can normally be removed by blowing the window surface using a compressed air blower, unless the dust particles are being held by an electrostatic charge, in which case either an ionized air blower or wet cleaning is necessary.

Oil is usually introduced during handling. Touching the surface of the window barehanded will leave oily residues. Using rubber fingercots and rubber gloves can prevent oil contamination. However, the friction between the rubber and the window may produce electrostatic charge that may damage the sensor. To avoid ESD damage and to avoid introducing oily residues, only hold the sensor from the edges of the ceramic package and avoid touching the sensor pins and the window.

Scratches can be caused by improper handling, cleaning or storage of the sensor. Vacuum picking tools should not come in contact with the window surface. CCDs should not be stored in containers where they are not properly secured and can slide against the container.

Scratches diffract incident illumination. When exposed to uniform illumination, a sensor with a scratched window will normally have brighter pixels adjacent to darker pixels. The location of these pixels changes with the angle of illumination.

Cleaning the Sensor Window

1. Use compressed air to blow off loose particles. This step alone is usually sufficient to clean the sensor window.
2. If further cleaning is required, use a lens wiper moistened with alcohol or acetone.
3. We recommend using lint-free ESD-safe cloth wipers that do not contain particles that can scratch the window. The Anticon Gold 9"x 9" wiper made by Milliken is both ESD safe and suitable for class 100 environments. Another ESD acceptable wiper is the TX4025 from Texwipe.
4. An alternative to ESD-safe cloth wipers is Transplex swabs that have desirable ESD properties. There are several varieties available from Texwipe. Do not use regular cotton swabs, since these can introduce charge to the window surface.
5. Wipe the window carefully and slowly.
6. When cleaning long linear sensors, it may be easier to wipe along the width (i.e. as opposed to the length) of the sensor.

Revision History

Revision Number	Change Description	Date
00	Revised Preliminary Version for Consignment Cameras	August 18, 2012
01	-Table 1: Updated performance specifications (were TBD) -Inserted Section 2: Quick, Simple Steps to Acquire an Image -Inserted Appendix B: Quick Setup and Image Acquisition -Appendix C: Date of issue updated (was TBD)	October 15, 2012

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